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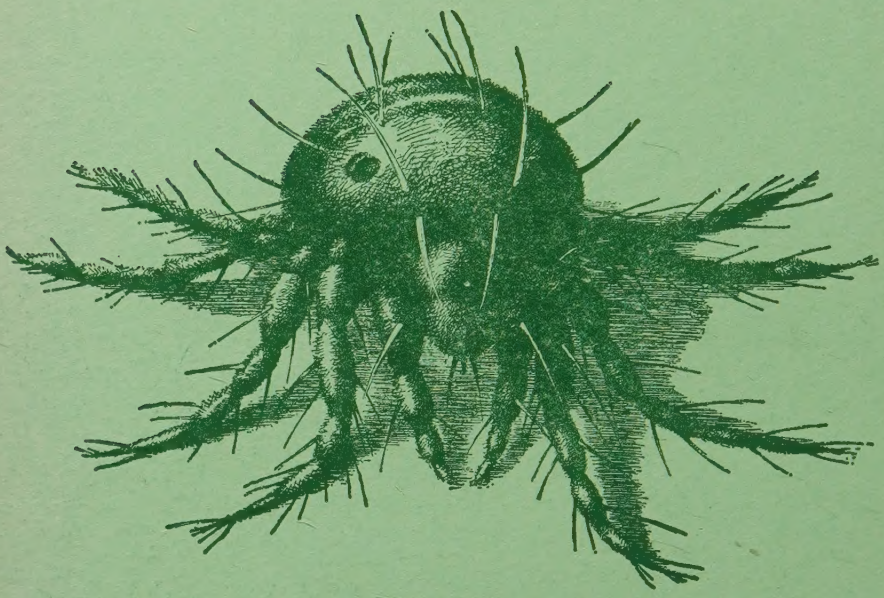

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Studies on the Depth and Rate of Root Penetration of Some Annual Tropical Crops

J. D. Lea

Agricultural Irrigation Research Station, University College of Ghana

This paper records the results of studies on the depth and rate of penetration of annual crop roots at the Overseas Food Corporation's* Research Station at Kongwa, Tanganyika, and at the Central Rainlands Research Station, Tozi, Sudan Republic. This work formed part of a wide programme of agronomic research at the two stations, the main results of which have been summarized by Bunting (1951, 1956).

Both Kongwa and Tozi have a semi-arid climate with a single rainy season of about five months each year, from December to April at Kongwa and June to October at Tozi. The rainfall at Kongwa is marginal for crop production: in the six years 1947–53, satisfactory crop yields were obtained in four seasons (1947–48, 1949–52) when annual totals fell between 18·8 in. and 22·7 in., but in two seasons, 1948–49 and 1952–53 with annual totals of 13·0 in. and 6·1 in. respectively, the crops failed. At Tozi the rainfall is more reliable, the normal value being about 27 in., and here there is some prospect of profitable large scale mechanized farming, though flooding on the heavy clays may be serious on cleared, level land in years of high rainfall. As a guide to the range of temperatures experienced at the two stations, mean monthly maximum and minimum air temperatures for Kongwa (1951) and Tozi (1955) are given in *Figure 1*, and soil temperatures for Kongwa (1951) only in *Figure 2*.

The main soil type on Kongwa Experimental Station is a red sandy loam (Chamaye Series of Anderson, 1957), moderately acid, with an acid subsoil, underlain by concretionary or sheet ironstone or acid gneiss, at 5 to 7 ft. At Tozi the soil is formed from a heavy, alkaline cracking clay, of considerable depth (over 20 ft). Physical analyses of the two soils are given in *Table 1*.

At Tozi, towards the end of the rains and in the dry season, the upper 3 ft or so of the clay breaks into dry and very hard, vertical prismatic blocks, separated by cracks. Below this the soil is slightly moist and just plastic; with pressure the clay can be moulded between the fingers. The moisture content is about 20 to 25 per cent, a little above the wilting point moisture content (18 to 20 per cent) for seedling cotton in pots in Gezira soil (Greene, 1948). At the onset of the rainy season some of the rainwater passes down the cracks, but these soon become sealed over. Thus, in the first part of the rains, after all the cracks have sealed, an upper layer of moist soil is underlain by dry cracked soil, and the dividing line can be

* Now Tanganyika Agricultural Corporation.

quite clearly seen in root bisect pits. Later, as the moisture penetrates to the zone at or near wilting point, the division is less clear.

At Kongwa 1 in. of water will bring about 8 in. of profile from wilting point to field capacity. At Tozi, where more water is lost by surface evaporation, the equivalent amount is 3 to 4 in. of profile.

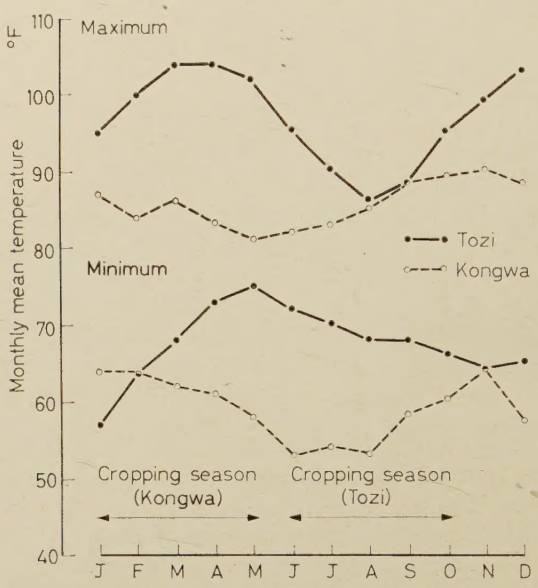

Figure 1. Maximum and minimum air temperatures at Kongwa (1951) and Tozi (1955)

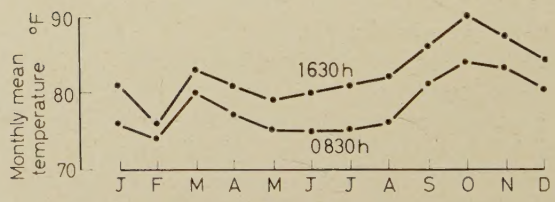

Figure 2. Soil temperature at 1 ft, Kongwa (1951)

Table 1. Mechanical analyses of soils at Kongwa and Tozi

Material	*Kongwa, sandy loam*	*Tozi, alkaline cracking clay*
Clay	23·1	71·4
Silt	3·3	11·8
Fine sand	15·4	15·9
Coarse sand	55·3	0·7
Stones and gravel	0·7	0·7

METHODS

The root bisect method of WEAVER (1919) was used to determine root depth. The roots were exposed by removing the soil with sharpened wire needles and by washing with a water jet at 10 to 40 lb/in^2 pressure. On the sandy loams at Kongwa the tap root and first and second degree laterals could readily be traced to their growing points; on the heavy clays at Tozi root excavation was more difficult, and the bisects had sometimes to be discontinued before crop maturity because of cracking. In the rate of penetration studies three to four pits were normally dug at random in the crop at approximately 10 day intervals. The tap roots (or major laterals when the tap root was damaged or broken) of about five plants were examined in each pit.

ROOT PENETRATION AT KONGWA

At Kongwa the roots of groundnuts, cotton and castor were examined at maturity in 1951. This work was extended in 1952 when the vertical elongation rate of groundnut tap roots was measured. Rainfall in both years was favourable, the seasonal totals being 20·9 and 22·7 in. respectively.

Groundnuts (*Figure 3*)

The mean depth of penetration at 10 and 20 day intervals and the average daily extension of Natal Common (maturation period, 105 days)

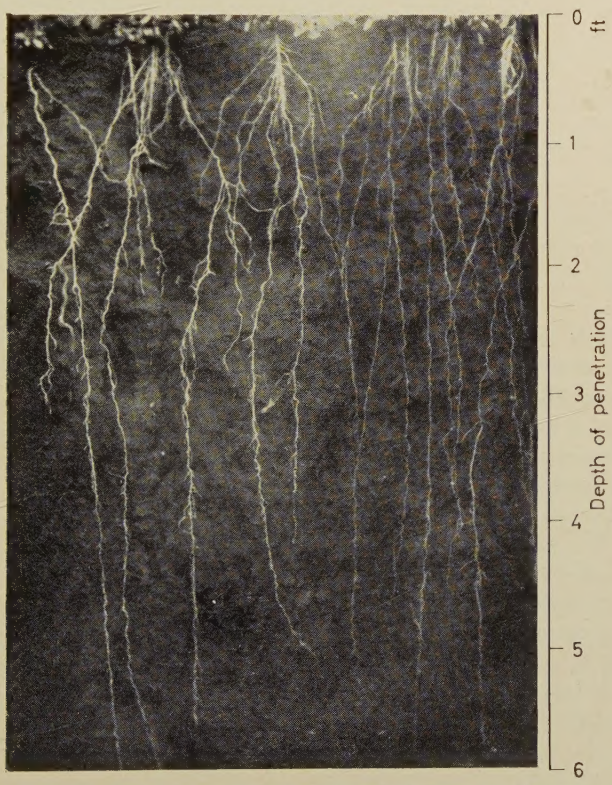

Figure 3. Root system of groundnuts (Natal Common), Kongwa

groundnuts in 1952 is given in *Table 2*. The crop was sown on 11 January in 34 in. rows with the plants spaced at about 4 in. in the row.

The radicle, which grows extremely rapidly in the early stages of growth, breaks the testa and emerges within 24 hours when the soil is moist. Laterals first appear at 4 to 6 days from planting when the tap root is about 5 in. long. The growth of the radicle is accompanied by elongation of the hypocotyl which remains succulent during the early stages of growth. Later the tissues harden, and at around 35 days from planting the hypocotyl produces adventitious lateral roots.

As may be seen in *Table 2*, penetration of the tap root in 1952 was most rapid during the first 50 days of growth. The mean daily extension during this period was 1·12 in./day. At 60 days two out of eight tap roots measured penetrated ironstone at 70 in. and in the preceding 10 days the penetration

Table 2. Depth of penetration and mean daily extension of groundnut roots, Kongwa, 1951–52

Days from planting	*Depth in.*	*Mean daily extension in preceding period in.*
10	12·4	1·24
20	22·9	1·05
30	34·8	1·19
40	40·6	0·58
50	55·8	1·52
60	62·0	0·62
80	65·0	0·15
100	68·3	0·16

rate had fallen to 0·62 in. per day. In the last 40 days, as the plants approached maturity and when more of the roots entered ironstone, the mean daily extension decreased to 0·16 in./day. The final mean depth was 68 in.

In addition to the elongation rate studies, the root systems of 22 mature groundnut plants were examined in 1950–52. In very nearly all cases the roots reached 5 to 7 ft, and then entered ironstone or weathered bedrock. The primary laterals spread obliquely or horizontally and then turned downwards to follow a vertical path. The larger primary laterals, originating from the top 6 in. of the tap root, often descend to the same depth as the tap root.

Castor and cotton (Figure 4)

The root system of cotton* (variety Uk48) and castor (Dwarf Hungarian, and a tall variety, Tel Aviv 21) were examined at maturity. The tap roots and laterals of both crops, many of which followed an oblique or horizontal path before turning downwards, were traced into ironstone at 6 to 7 ft. Second and third degree laterals often followed a similar path.

* Although cotton made good vegetative growth at Kongwa, the bolls were completely destroyed by American bollworm and Dysdercid stainers.

ROOT AND RAINWATER PENETRATION AT TOZI

Rainwater penetration

The depth of rainwater penetration was measured by inspection at successive dates in the root bisect pits (see below), and in 1955 in (*i*) adjacent areas under *Acacia seyal* woodland with a ground flora mainly of tall annual grasses; (*ii*) cotton (after late sown safflower in 1954), planted on 28 June after the normal preparation with light discs; and (*iii*) bare fallow (sorghum in 1954). The results are shown in *Table 3*.

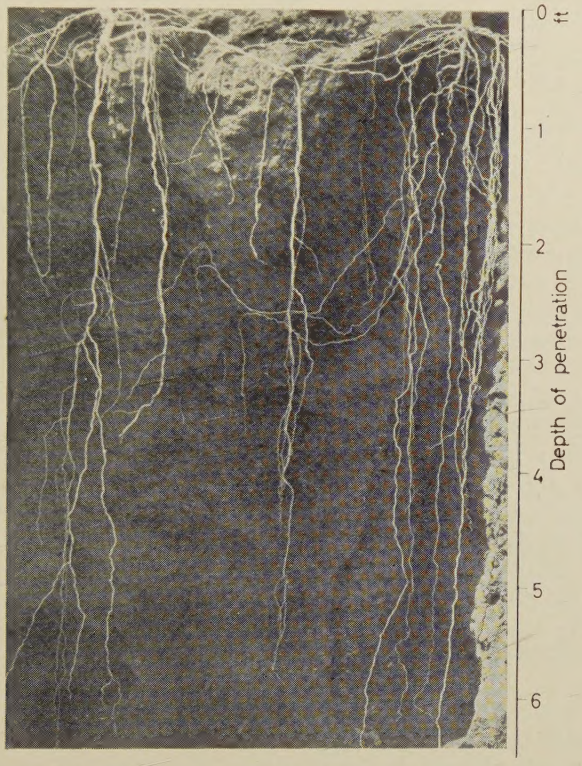

Figure 4. Root system of cotton (Uk 48), Kongwa

(i) *Bush plot*—In the bush plot active growth and utilization of water began early in June. Rainwater had penetrated to 8 in. by 21 July, and only very slightly farther by 11 August. Heavy rain, totalling over 3 in., fell during the next week and this increased the penetration to 12·9 in., after which no further penetration took place in spite of heavy rain in September. Presumably percolation in this period was balanced or more than balanced by transpiration. The grass wilted markedly during the two dry periods (21 to 27 July, 3 to 11 August). The top 12 in. of soil was filled by a mass of fine grass roots which penetrated to the same depth as the moisture. Larger (perennial) tree roots were also seen, and in many cases these went much deeper than the current season's moisture.

Table 3. Rainwater penetration in adjacent areas under bush (Acacia seyal *woodland with tall grass), cotton (sown on 29 June) and bare fallow, Tozi, 1955*

Date	Rainfall, cumulative in.	Mean depth of penetration Bush in.	Cotton in.	Bare fallow* in.
21 Jul	8·98	8·2	14·4	—
27 Jul	9·32	7·0	13·3	—
3 Aug	11·45	9·8	16·4	—
11 Aug	11·68	9·4	18·3	23·0
20 Aug	15·14	12·9	23·0	32·0
25 Aug	16·56	11·3	22·6	—
1 Sep	16·72	12·9	24·9	32·8
8 Sep	17·86	10·9	26·1	39·0
15 Sep	20·26	12·5	23·0	43·3
21 Sep	21·78	16·0	22·6	47·2
2 Oct	23·04	13·6	22·6	49·9

* A dash in this column denotes that the depth of moisture penetration was not measured.

(ii) *Cotton plot*—The cotton showed no signs of wilting throughout the season, and produced 1 200 rotls per feddan* seed cotton. Although moisture penetration followed a similar course, it was consistently deeper than in bush, presumably because all the effective rainfall before the end of June had accumulated. On 21 and 27 July the depth of penetration was about 13 to 14 in., 6 in. deeper than in bush. By 20 August, and after a further 4 in. of rain had fallen, penetration had increased to nearly 2 ft, about double that in bush. This relative gain suggests a higher total transpiration in the bush, doubtless due to the earlier establishment there of full cover and maximum transpiration rate. After 20 August the level of penetration remained more or less constant for the remainder of the season, as in bush.

(iii) *Bare fallow*—The rate of penetration under bare fallow was roughly constant as the depth increased from nearly 2 ft on 11 August to a little over 4 ft on 2 October. At the end of the season moisture penetration under bare fallow was 2 ft depeer than in the cotton plot, and 3 ft deeper than in the bush.

Root penetration

The depth and vertical penetration rates of groundnuts, sesame, sorghum and cotton roots were measured in 1953–55.

Groundnuts and sesame—Two acres each of sesame (Black Heavy) and groundnuts (Natal Common) were planted on the 16 to 17 July 1953. The roots were exposed at three points in each crop at approximately 10 day intervals and depths of both moisture and root penetration were measured. The results are shown in *Tables 4* and *5* and *Figure 5*. In *Figure 5*, groundnut root penetration at Kongwa is included for comparison with that at Tozi.

In pits dug at 11 and 21 days from planting the upper layer of moist soil extended to 20 in., and this was underlain by dry, cracked soil. At 31 days from planting and after a further 3 in. of rain, the penetration had increased to 24 in. Rainfall in the following 10 days included a 2·20 in.

* Approximately equivalent to lb/acre.

storm and the moisture had reached 31 in. at 40 days from planting. The moisture line at the time of the later observations was indistinct as it had merged with the persistently moist zone to which, in addition, water flowing down the cracks at the beginning of the season had penetrated.

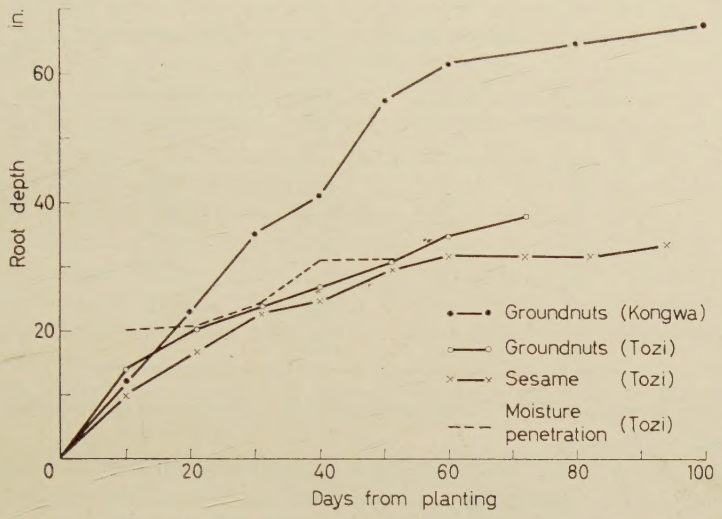

Figure 5. Penetration of groundnut roots at Kongwa (1952) and of groundnut and sesame roots at Tozi (1953)

The groundnut tap roots penetrated very rapidly in the first 11 days, the rate being 1·31 in./day, very nearly the same as at Kongwa (1·24 in./day). This was followed by a marked decline when the roots met dry soil and subsequent root depth was approximately the same as moisture penetration.

Table 4. Depth of penetration and mean daily extension of groundnut roots, Tozi, 1953

Days from planting	*Moisture penetration in.*	*Root depth in.*	*Mean daily extension in preceding period in.*
11	20	14·4	1·31
21	20	20·3	0·59
31	24	23·8	0·35
40	31	26·9	0·34
51	31	31·2	0·39
60	—	35·9	0·52
72	—	37·8	0·16

At 72 days from planting the tap roots had reached a depth of 37·8 in. In the following 10 days the soil hardened and cracked, and at the end of the period the roots could not be traced to their growing points. The final depth at maturity is, therefore, not known.

Sesame roots grew less rapidly than groundnuts but the dry layer appears to limit their growth in the same way. There was a marked decline in

root penetration at 60 days from planting and onwards. Cracking was less severe in the sesame plots, and the bisects were continued to maturity. The final depth was 33 in.

Sorghum—The roots of a dwarf sorghum (Combine Kafir 60) sown on 7 August, on a comparatively well drained site, were examined at four

Table 5. Depth of penetration and mean daily extension of sesame roots, Tozi, 1953

Days from planting	*Moisture penetration in.*	*Root depth in.*	*Mean daily extension in preceding period in.*
11	20	9·4	0·85
21	20	17·2	0·78
31	24	22·6	0·54
40	31	25·0	0·27
51	31	30·4	0·49
60	—	31·6	0·13
72	—	32·4	0·07
82	—	32·4	0·00
94	—	32·8	0·03

successive dates in 1954. Root and moisture penetration is shown diagrammatically in *Figure 6*.

At 12 days from planting, the single primary seminal root had reached a depth of 17·9 in. The elongation rate was thus 1·49 in./day—slightly faster than groundnuts over the same period. At 22 days the seminal roots, which produced a mass of threadlike laterals extending to 8 in., were traced to a depth of 25·4 in. (1·15 in./day from planting). Subsequently seminal roots were not traced below this depth.

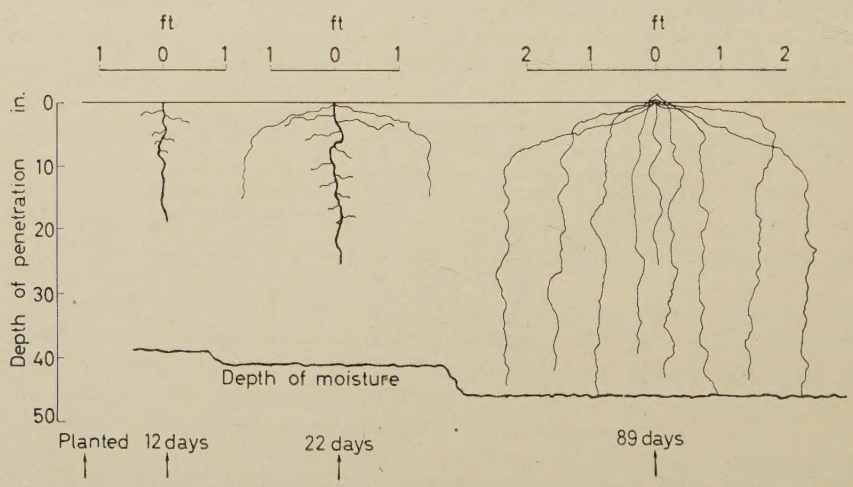

Figure 6. Root system of dwarf sorghum at 12, 22 and 89 days from planting, Tozi, 1954

The adventitious roots grow in successive whorls from basal stem nodes, situated either just below or just above ground level, so that the soil continually contains a mass of young elongating roots. At first these roots follow a more or less horizontal path before turning, sometimes abruptly

but more usually with a gentle curve, to penetrate vertically. Later in the season, when the surface soil began to dry, the roots did not follow an initial lateral path but penetrated either vertically or obliquely from nodes above the ground.

At three weeks from planting, adventitious roots extended to a maximum lateral distance of 15·6 in. and to a maximum depth of 14·4 in. Subsequently these roots were followed to a maximum of 23·4 in. laterally before they turned down to follow a vertical path. On the final date of examination, at 89 days from planting, when the grain was in the soft dough stage, the depth of root penetration was 43·3 in.; the depth of moisture penetration at this time was about the same. No further bisects were made as the upper 1 ft of soil had hardened and cracked so that the roots could not be traced from their origin on the plant.

Cotton—The root system of variety BAR 7/8.1, sown on 12 July in 32 in. rows, was examined at seven successive dates in 1953. Flooding was particularly severe in that year, and a shallow depression, adjacent to the slightly more elevated part reserved for root studies, was under water for most of the rains.

The depths of root and moisture penetration are given in *Table 6*.

Table 6. Depth of penetration and mean daily extension of cotton roots, Tozi, 1954

Days from planting	*Moisture penetration in.*	*Root depth in.*	*Mean daily extension in preceding period in.*
14	26·0	18·9	1·35
23	28·8	16·2	—
35	31·1	17·7	—
48	32·7	18·9	—
61	35·1	19·3	—
78	35·5	22·8	0·20
107	37·4	31·9	0·31

Fourteen days after planting, when the cotton was about 4 in. high, the mean depth of root penetration was 18·9 in. (1·35 in./day). Water, in excess of field capacity, was present below a depth of about 16 in. for practically the whole of the period from about three weeks to two months from planting. At three weeks water oozed from the soil face, and at 35 days water flowed freely into two of the four bisect pits. This prevented further vertical penetration and many roots were killed through excess moisture.

At 48 days the soil was still very wet but no water flowed into the pits. At this date four out of five tap roots excavated had produced new roots which grew from a point just above the section killed by excess moisture. Similar regrowth occurs after cotton roots are killed by a rising water table in the Nile delta (Balls, 1919, 1951). Despite this new growth the mean root depth at 61 days was no deeper than at 14 days, and only slightly deeper at 78 days. From then onwards, however, as the surface soil dried out and cracked, the roots continued to penetrate into moister

soil below and at the final date of examination the mean depth was 31·9 in. At that time the water penetration had reached 37·4 in.

In the following year (1955), cotton roots were examined at successive dates on two fields, one of which, in 1954, had been half-fallowed (BUNTING, 1956) while the other was under late sown safflower. Although bare fallowing at Tozi checks subsequent crop growth, half-fallowing has a beneficial effect (BUNTING, 1956). This half-fallowed field gave the Tozi record yield of 2 200 rotls per feddan seed cotton.

Before the onset of the 1955 rains the uppermost 10 in. of soil on the half-fallow field was dry; below this it was very moist down to 4 ft. On the late sown safflower field the soil was dry and cracked down to 4 ft.

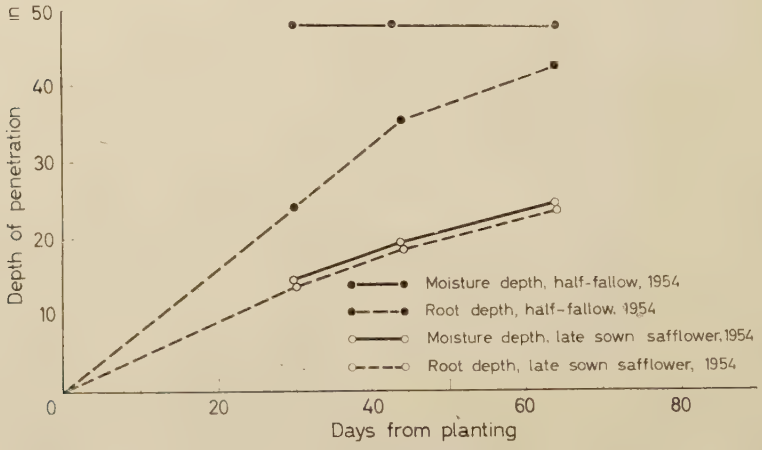

Figure 7. Moisture and cotton root penetration on land under late sown safflower and half-fallow in the previous year, Tozi, 1955

The depths of root and moisture penetration on both fields during the season are shown in *Figure 7*. Cotton roots on the late sown safflower field followed the moisture down the profile, in the same way as groundnuts and sesame in 1953. The final depth of roots and moisture was 22·6 in. On the semi-fallowed field the depth of roots at 30 days from planting was 2 ft, the vertical elongation during the first 30 days of growth was thus 0·80 in./day. Two weeks later the mean depth was 35 in., and the elongation rate was still 0·80 in./day. At the final examination, 64 days from planting, the roots had reached 42 in., very close to the limit of moisture penetration. The vertical elongation rate in this last period had fallen to 0·32 in./day, less than half the initial rate.

The maximum penetration rate, 0·80 in./day, was comparatively low considering that the roots were growing in moist soil. In 1954 cotton roots grew at 1·35 in./day during the first 14 days before their growth was checked by waterlogging, and an average penetration rate over 3 months of up to 1·10 in./day is recorded by BALLS (1951) for cotton growing at Giza in the Nile delta.

DISCUSSION

On the red sandy loams at Kongwa Experiment Station there is apparently no restriction on the vertical penetration of groundnut, cotton and castor roots in seasons of favourable rainfall; the roots extend through the whole profile and into underlying ironstone or weathered gneiss at 5 to 7 ft. On the same soils on Unit 3 at Kongwa, about 20 miles from the Experiment Station, PEREIRA *et al.* (1958) found that maize and sorghum had a similar root range to groundnuts, cotton and castor. The rate of penetration of groundnut roots is remarkably rapid: within 60 days the roots reach 6 ft depth. As may be seen in *Figure 8* which shows root elongation and dry matter accumulation (BUNTING and ANDERSON, 1960) of Natal Common groundnuts, the plants are thus able to absorb moisture and nutrients from very nearly the full depth of soil for the whole period of most rapid growth.

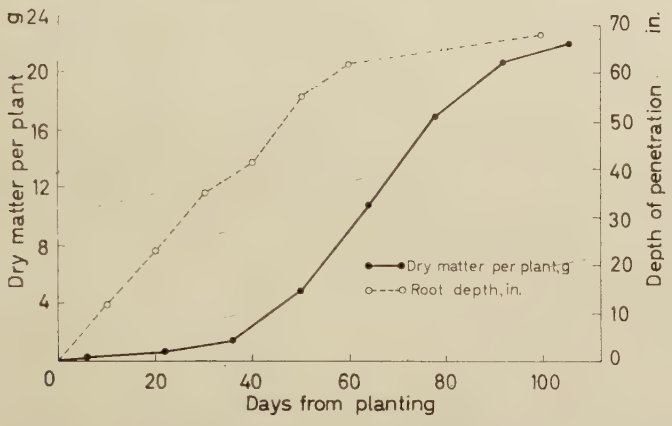

Figure 8. Root penetration and growth of Natal Common groundnuts, Kongwa

Furthermore, at the time of maximum dry matter accumulation in the pods and kernels at 65 to 80 days from planting (BUNTING and ANDERSON, 1960), the roots are fully grown and have penetrated underlying rock.

On the impermeable clay soils at Tozi moisture penetration is slow, and vertical root growth is often limited by dry soil underlying that wetted by the current season's rainfall, or by waterlogging. The depth and rate of moisture penetration in the field, and hence root growth, is influenced by the amount and distribution of rainfall, particularly the incidence of intense storms early in the season and the time of sealing of the cracks; by the loss of soil moisture by transpiration from both crop and weeds, and from bare ground before complete leaf cover is obtained; by agricultural practice, such as crop sequence and time of planting, and, finally, by water run-off or accumulation.

At harvest, the upper 2 to 3 ft of soil in cotton, groundnut, sorghum and safflower fields is cracked and dried to well below wilting point. Below this the soil is at or near wilting point (about 20 per cent). On these fields, in the following year, the roots of early planted crops penetrate rapidly

(0·8 to 1·3 in./day) at first but at about three weeks from planting further penetration is held up by dry soil at 1 to 2 ft, and from then onwards the roots follow the moisture down the profile. After a half-fallow, and to a lesser extent after sesame and maize (see below), a reserve of soil moisture is carried over from one season to the next, and once the surface soil is wet, the roots penetrate into a comparatively deep (4 to 5 ft) layer of moist soil. The effect of later planting is similar. Fields reserved for late sown crops are kept more or less free from weeds, and hence moisture loss by transpiration is low. Consequently a reserve of moisture accumulates and, at planting, the depth of moisture may be as much as 3 ft. There is thus no shallow underlying dry layer to stop vertical penetration and the roots penetrate freely into moist soil during the first 1 to 2 months of the crop's life, though finally they extend to the limit, or nearly so, of the moisture.

On the clay plains very slight changes in level lead to run-off and ponding in seasons of heavy rainfall. The larger depressions can be located by ecological and topographical survey before clearing and so excised from the cultivated area (Bunting and Lea, unpublished data). Flooding is, however, more prevalent on cultivated land than in bush. In the bush transpiration begins with the first flush of growth at the onset of the rains. On cultivated land this early transpiration loss does not occur as the land is kept clean in preparation for planting. Severe flooding leads to stunted growth and to death of roots in waterlogged layers. As the soil dries out regrowth occurs but the crop does not yield as well as on better drained sites.

At Tozi, in addition to the factors described above, the depth of soil exploited for nutrients and moisture depends to some extent on the root behaviour of particular crops. In this respect sesame appears to have a less efficient root system than other crops. In the early stages of growth, at least, the penetration rate is slower than for cotton, sorghum and groundnuts. Maize probably behaves in the same way: in observation pits dug in mature maize in 1956 the soil was moist below 1 ft.

SUMMARY

The depth and rate of root penetration of certain annual crops were measured at Tozi, Sudan Republic, and at Kongwa, Tanganyika. At Kongwa the soil is a sandy loam (23 per cent kaolinitic clay) and at Tozi an alkaline cracking clay (71 per cent montmorillonitic clay). Both areas have a semi-arid climate, with a single rainy season each year lasting for about five months, the mean seasonal totals being around 20 in. at Kongwa, with considerable seasonal fluctuation, and at Tozi 27 in. with less fluctuation.

At Kongwa the roots of groundnuts, cotton and castor extended through the full depth of the profile, and entered underlying ironstone or weathered gneiss at 5 to 7 ft. Groundnut roots penetrated at an average rate of 1·12 in./day in the first 50 days of growth, and then more slowly (0·2 to 0·6 in./day) as the roots approached weathered rock. At the time of maximum dry matter accumulation in pods and kernels (65 to 80 days from planting), very nearly all the tap roots had penetrated ironstone or gneiss.

On the heavy clays at Tozi rainwater penetration is slow and roots of groundnuts, cotton and sorghum follow the moisture front down the profile. The maximum recorded depth of crop root penetration at Tozi was 3·5 ft.

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Bacterial Wilt of Bananas: History and Known Distribution

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Bacterial wilt of bananas, often called Moko disease, was known as early as 1910 in Trinidad and was well described by Rorer (1911). Subsequently, the disease has been reported from many parts of the world (reviews by Wardlaw, 1935; Kelman, 1953). Some of the reports were substantiated by pathogenicity studies, but the majority mentioned only isolation of bacteria and the probable similarity of the disease to the Moko disease in Trinidad. After the causal agent of Moko disease was proven to be *Pseudomonas solanacearum* E. F. Sm., it was natural that bacteria isolated from wilt-diseased banana plants could sometimes be considered to be this organism, in the absence of pathogenicity studies. Reports, unconfirmed by pathogenicity studies, have created the impression that the disease is widely distributed. The importance of the disease in Central America has resulted in an intensification of research in recent years. The purpose of this study was to determine the distribution of the disease. A survey trip was made through northern South America and several Caribbean islands to observe the disease in those areas. Information presented in this paper includes a critical revaluation of the literature based on our present understanding of the disease in Central America. A description of the disease is also provided so that suspected Moko-diseased plants may be more readily identified and possible new areas added to the distribution known today.

DESCRIPTION OF THE DISEASE

Bacterial wilt of bananas is known generally as Moko disease, although it is referred to as ' Hereque ' in Venezuela. It is caused by a strain of *Pseudomonas solanacearum* distinct from the strain causing bacterial wilt of solanaceous crops throughout the warm regions of the world (Buddenhagen, 1960). The disease may affect any of the commonly grown bananas or plantains; symptoms are similar on all varieties. This is in marked contrast to Panama disease, caused by *Fusarium oxysporum* f. *cubense* (E. F. Sm.) Snyd. and Hans., which affects ' Gros Michel ' and only a few other edible varieties of *Musa* planted in the Western Hemisphere.

Symptomatology of the disease has been described several times (Rorer, 1911; Ashby, 1928; Wardlaw, 1935; Sequeira, 1958). However, for those not acquainted with the disease, confusion readily arises with *Fusarium* wilt, and with other disease conditions. The disease affects plants at all

* A subsidiary of United Fruit Co.

stages of growth but symptoms are most characteristic on young, rapidly growing plants. The first, second or third leaf becomes yellow-green followed by collapse at or above the juncture of petiole and lamina, *Figure 1*. Subsequently the lower leaves also wilt and collapse. Collapse may occur while the leaves are still green or are only slightly off-colour. The symptoms progress rapidly; on young, actively growing plants a few days to a week elapse from initial leaf symptoms to collapse of most of the leaves. Necrosis may occur on the lower portion of the lamina. Young suckers only 1 to 3 ft in height commonly show symptoms. The disease is characteristically seen on regrowth suckers 2 to 4 weeks after pruning, *Figure 2*. Such suckers may be blackened and stunted before a new leaf develops, or a few new leaves may develop before wilting occurs, *Figure 3*. Since the disease is transmitted on pruning knives (SEQUEIRA, 1958) it is common for an initial infection to show up on adjacent regrowth suckers after pruning. In plantations where pruning is done below the soil surface to eliminate growing points, regrowth suckers will not occur, and symptoms will appear only on uncut suckers, where they are less noticeable. Leaf symptoms of mature plants resemble those of suckers but are more easily confused with *Fusarium* wilt.

The vascular strands of diseased pseudostems are usually light to dark brown. In young suckers a water-soaked appearance is often present in the leaf sheaths. The discoloured strands in plants not yet bearing fruit are concentrated immediately outside the centre of the pseudostem, becoming less frequent peripherally and centrally, *Figure 4*. The most extensive discoloration occurs in the sheaths of the leaves initially wilting. The discoloured xylem vessels are full of minute gram-negative rods; bacteria that appear similar may occur with other banana diseases. Vascular discoloration in the rhizome is also extensive, especially in the stele adjacent to the cortex, and extending in the stele to the lateral buds. Vascular discoloration of the rhizome and pseudostem resembles that of *Fusarium* wilt but differs in several respects. With *Fusarium* wilt, discoloured strands are usually concentrated more peripherally in the pseudostem and their colour is usually more yellow or more red-crimson than with bacterial wilt. With *Fusarium* wilt, discoloration of individual vascular strands in the pseudostem appears larger in diameter and rhizome discoloration does not extend into the buds to the same extent as with bacterial wilt. Differences in vascular discoloration between the two diseases may at times be confusing, and are of use mainly to persons experienced in diagnosis. Droplets containing bacteria may exude from cut surfaces of plants with Moko disease but rarely do so in Panama disease cases.

Bacterial wilt has also been termed ' dry rot ' because of the characteristic fruit symptoms. When bacterial wilt is present in a plantation some fruit bunches will not develop normally; the fruit bud will be small and may wither and fruit development is arrested. Internally, the fruit pulp is discoloured by a firm brown rot that develops to a grey dry rot. A lightly affected stem may show limited external symptoms consisting of a few split or prematurely yellow fingers, *Figures 5* and *6*. The fruit stalk will exhibit vascular discoloration, concentrated peripherally, *Figure 7*.

Symptoms used for positive identification of the disease are: (*1*) fruit

Figure 1. Characteristic Moko disease symptoms. Note colour and position of collapse of first and second leaf

Figure 2. Deformed and blackened regrowth suckers three weeks after pruning with a contaminated machete

Figure 3. A diseased regrowth sucker that produced new leaves before showing symptoms

Figure 4. Moko disease symptoms in pseudostem. Note position of most severely affected leaf sheaths

rot and fruit stalk discoloration; (*2*) wilting or blackened regrowth suckers. Without both of these symptoms in a new suspected wilt-diseased area, the presence of bacterial wilt is doubtful.

A different syndrome, termed ' distortion ', may occur with some strains of the pathogen, *Figure 8*. Instead of wilting rapidly, the plants remain alive but are stunted. New leaves that are produced are narrow and may be twisted. The leaf sheaths separate and become twisted, deformed and later blackened. Internal vascular discoloration is the same as with the normal or rapid wilt syndrome. The distortion syndrome is especially evident when it occurs on young plants; it may eventually result in their death, or it may be so benign that the plant will live to produce fruit which may exhibit typical internal symptoms.

Most diseases with which Moko disease might be confused are not readily transmitted on pruning knives. For attempted transmission work, symptoms should appear 2 to 4 weeks after cutting healthy young suckers with a knife previously used to cut a suspected wilt-diseased pseudostem. If isolation of the organism is attempted, it is most successfully done by placing slices of vascular tissue in sterile water and streaking from the resultant bacterial suspension on to a tetrazolium medium (KELMAN, 1954; HUSAIN and KELMAN, 1958). By the use of the tetrazolium medium, colonies of *P. solanacearum* may be distinguished visually.

HISTORY OF THE DISEASE AND LITERATURE REVIEW

Substantiated reports of Moko disease

The earliest known reference to what probably was bacterial wilt of bananas was recorded by SCHOMBURGK in 1840 from the island of Wakenaam in British Guiana (MARTYN, 1934). In his interesting account he states: ' For some years past, an extremely peculiar disease has introduced itself in the Musa plantations: this has become particularly dangerous owing to its having proved so infective that if one shaft is attacked, the whole plantation follows suit and perishes. The disease itself starts from the innermost vascular bundles which take on a brownish colour intermixed with a number of black spots . . . The growth of the plant as well as that of the fruit is arrested and a resinous exudation renders the latter absolutely uneatable . . . Experience has taught that even the suckers contain the diseased material of the mother plant . . . Ten years ago the pest was completely unknown . . .' That this was probably Moko disease is supported by the fact that the disease is severe on Wakenaam today, 120 years later. The description of the fruit symptoms exactly corresponds to the appearance of diseased fruit of the ' Moko ' or ' Bluggoe ' plantain when it is cut. Also, *Fusarium* wilt, the one disease with which bacterial wilt might have been confused, could not have been involved since *Fusarium* wilt does not produce such fruit symptoms. Furthermore, the *Fusarium* wilt-susceptible variety ' Gros Michel ' was not yet distributed to British Guiana. No mention of the disease appeared again until Stockdale in 1909 stated it had been present for a long time and was more prevalent in wet years (MARTYN, 1934). Additional reports of its occurrence in British Guiana have appeared from time to time (BANCROFT, 1918; ALSTON, 1926a, 1926b, 1927; ASHBY, 1928, and subsequent internal reports in British Guiana).

Figure 5. A lightly affected Moko-diseased fruit stem. A few fruits are split, small or slightly deformed

Figure 6. The same stem as in Figure 5, cut to show internal symptoms. Note apparent randomness of the rotten fruits

The first work on the disease substantiated by isolation of the bacterium and proof of its pathogenicity was carried out in 1909 by J. B. Rorer in Trinidad (Rorer, 1910a, 1910b, 1911). In his excellent work he noted similarities to *Bacillus* (now *Pseudomonas*) *solanacearum*, and found that varieties ' Gros Michel ', ' Giant Governor ', red banana and ' French ' and ' Creole ' plantains were susceptible. He advised great care in selecting planting stock and stated that ' when diseased plants are destroyed all implements

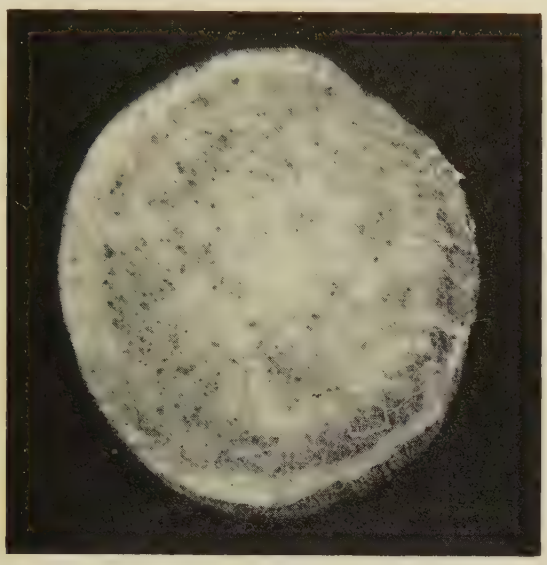

Figure 7. Vascular discoloration of the fruit stalk

should be thoroughly disinfected '. After 50 years these two recommendations are still among the most important recommendations for control of the disease. The disease almost exterminated the ' Moko ' plantain from Trinidad, starting about 1895. A report of a disease that was probably

Figure 8. The ' distortion ' syndrome on a young banana plant 45 days after inoculation. Characteristic symptoms are stunting, narrow new leaves, and splitting of the older leaf sheaths

identical appeared even earlier from Trinidad (HART, 1894). Subsequently many reports of the disease in Trinidad have appeared (ASHBY, 1926, 1927; STELL, 1934, 1935, 1936; WARDLAW, 1934; WILLIAMS, 1943; MARTYN, 1952). Several interesting points were made in these reports. The bacterium was pathogenic to solanaceous plants following inoculation and was established as *P. solanacearum* E. F. Sm. (ASHBY, 1926). Ashby believed, however, that the literature dealing with the disease on other crops thereby became pertinent to bananas. This is now known to be not strictly true. Although the banana strain is pathogenic to tomatoes following stem inoculations, it is now known that the solanaceous strain does not affect bananas (BUDDENHAGEN, 1960). Ashby also expressed surprise that the disease was not reported from Sumatra where so many hosts were known.

The disease was repeatedly mentioned as being worse in areas recently cleared from jungle, and jungle conditions existed when the epidemic originally occurred in Trinidad on plantains used for shade accompanying expansion of cocoa plantings (STELL, 1934). Stell also mentioned that a *Heliconia* sp. was attacked ' by a bacterial disease which is apparently identical with the one affecting " Moko " plantain '. It is strange that the banana variety ' Gros Michel ' was considered initially to be quite resistant, and natural infection of this variety was not observed until 1934 (WARDLAW, 1934).

Moko or Hereque disease was reported from Venezuela in 1941 (MULLER, 1941), and later (STANDEN, 1952). Although these reports were not accompanied by definite proof based on inoculation tests, it is now known to be widely distributed in Venezuela (WEBSTER and MALAGUTI, personal communication, 1959, and observations).

The most recent reports of the definite presence of bacterial wilt in a new area involved United Fruit Co. plantations on the Pacific Coast of Costa Rica (SEQUEIRA, 1956; SEQUEIRA and WAITE, 1956). By 1956 it was known to be present in adjacent ' Gros Michel ' plantings in Panama, on the northwest Caribbean coast of Panama, and in Honduras. On the east coast of Panama and in Honduras bacterial wilt appeared following introduction of banana rhizomes from countries where it was already present. Early Company records indicated that the disease was first recorded as ' dry rot ' on fruit reaching the U.S.A. from Golfito, Costa Rica in January 1948. Expansion of banana cultivation to new areas recently cleared from virgin jungle in southern Costa Rica occurred at approximately the same time. Subsequent disease incidence reached alarming proportions and resulted in an expanded research programme which is still continuing.

Other reports of bacterial disease

A detailed description of a bacterial disease of ' Dwarf ' and ' Giant Cavendish ' near Santos, Brazil appeared in 1933 (WARDLAW and MCGUIRE, 1933). Although it was considered to be Moko disease, proof was not definite since inoculations did not duplicate the condition described, and the authors concluded that the pathogen ' may provisionally be referred to *P. solanacearum*, the causal agent in the West Indian bacterial wilt disease '. WARDLAW (1935) in his later review included the Brazilian disease with bacterial wilt and the symptoms in Brazil constitute the main description

of the disease. This has been confusing since the symptoms in Brazil differed considerably from the symptoms illustrated originally (RORER, 1911) and from those considered characteristic of bacterial wilt today. The following points mentioned by Wardlaw and McGuire make the identity of the Brazilian disease questionable:

> Vascular discoloration of pseudostems was inconspicuous, yellow vascular discoloration being present only in the outermost leaf sheaths in advanced cases; ' otherwise vascular discoloration was absent even in the trunk, close to the soil, the rhizome itself, and in the infected suckers '. ' In the Giant Fig (Cavendish) the disease only appears at a late stage in the development of the plant and well grown daughter plants appear quite healthy '. No mention was made of a fruit pulp rot, the most definite symptom of Moko disease. ' The typical yellow discoloration of the vascular strands was found to be associated with the tannin ducts, and not with the wood vessels themselves ' (which is not the case with Moko disease). Inoculations of petioles with the bacteria isolated produced a yellow vascular discoloration of only 5 cm within 16 days. The ' tabatinga ' soils on which the disease chiefly occurred were described as having a thin rich humus layer overlying a wet compact bluish clay. Roots penetrating the clay exhibited much necrosis.

All of these atypical symptoms, as well as the soil conditions, were similar to a condition observed by the writer and L. Sequeira in a ' Giant Cavendish ' plantation in the Estrella valley on the Caribbean coast of Costa Rica in 1958. Bacteria were readily obtained from the slightly yellow vascular strands but these were not pathogenic and the condition was definitely not Moko disease. On the other hand, certain symptoms described on 'Dwarf Cavendish' by Wardlaw and McGuire sufficiently resemble Moko disease symptoms recently observed by the writer on ' Dwarf Cavendish ' in Venezuela to leave the identity of the Brazilian disease in doubt. A later report from Brazil does not clarify the situation (DESLANDES, 1938).

Many cursory reports of a bacterial disease of bananas have come from various parts of the world and are noted in KELMAN's review (1953). In South America reports have appeared from Argentina and Paraguay (ZEMAN, 1922), Ecuador (DESROSIERS and DIAZ, 1956; DESROSIERS and AMPUERO, 1957) and Colombia (MEJIA FRANCO, 1937; VELASCO LLANO, 1944). In the West Indies reports have appeared from Dominica (ANON., 1934, 1937), Dominican Republic (MENOR, 1939), Guadeloupe (STEHLE, 1936, 1947; WARDLAW, 1937; ROGER, 1938), Haiti (WARDLAW, 1938, 1940), St Vincent (ANON., 1935), and Cuba (VENNING, 1958). It has been mentioned as being present in Nicaragua (ROGER, 1938). None of these reports provided sufficient information on isolation and inoculation experiments to show conclusive evidence that the disease described was Moko disease.

In Africa, Asia and the Pacific Islands, *P. solanacearum* has been mentioned in connection with a disease of bananas from Libya (CIFERRI and GADDINI, 1939; GADDINI and CIFERRI, 1940), French Guinea (HEIM, 1946), Somaliland (CURZI, 1934), Mauritius (SHEPHERD, 1927), Sierra Leone (DEIGHTON, 1936), Ceylon (PARK, 1930), Malayan Federation (WARD, 1928; SHARPLES, 1929; VOELCKER, 1953), Fiji (PARHAM, 1936), Hawaii (PARRIS, 1940). A disease of abaca (*Musa textilis*) in the Philippines (PALO and CALINISAN, 1939) and a disease of *Ensete* in Ethiopia (CASTELLANI, 1939) were considered to be caused by a bacterium similar to *P. solanacearum.*

Extensive information was reported on a 'bloedziekte' in the Celebes apparently due to a soil bacterium (GAUMANN, 1921a, 1923). In some respects the disease described resembled Moko disease. The Javanese vascular disease attributed to bacteria (GAUMANN, 1921b) is now generally agreed to be *Fusarium* wilt (WARDLAW, 1935). The symptoms described were not those of Moko disease.

In all of these reports the pathogenicity of the bacterium either was not sufficiently established, or the symptoms described were not indicative of Moko disease.

KNOWN DISTRIBUTION

Bacterial wilt of bananas is known to be present today in Trinidad, Venezuela, British Guiana, Costa Rica, Panama and Honduras, *Figure 9*. The varieties observed infected in these countries are presented in *Table 1*. The disease has not been definitely confirmed to be present in other countries and was not found in Ecuador, Martinique, Puerto Rico, Dominican Republic or Jamaica during the author's recent visit to those countries.

Table 1. Known distribution of bacterial wilt of bananas, and varieties affected

Country	*Variety affected**	*Also affected by* Fusarium *wilt*
Venezuela	*Topocho plantain*†	*Not recorded*
	Manzano (Apple banana)	*Yes*
	French plantain‡	*No*
	Dwarf Cavendish‡	*No*
	Gros Michel	*Not recorded*
	Lacatan group	*No*
Trinidad	*Lacatan*	*No*
	Giant Cavendish	*No*
	Horse plantain	*No*
	Moko plantain	*Not recorded*
	Heliconia bihai	*Not recorded*
	Heliconia *sp.*	*Not recorded*
British Guiana	*French plantain*	*No*
	Horse plantain	*No*
	Lacatan	*No*
	Heliconia psittacorum	*Not recorded*
Costa Rica	*Gros Michel*	*Yes*
	French plantain	*No*
	Heliconia *spp.*	*Not recorded*
Honduras	*Gros Michel*	*Yes*
Panama	*Gros Michel*	*Yes*
	Lacatan	*No*

* The varieties indicated are the principal varieties grown in the different countries for home use or trade. Plantains and wild Heliconia are included.

† Topocho plantain of Venezuela is the original Moko plantain of Trinidad and is elsewhere known as Bluggoe, Whitehall, Chato, Cacambou, Maricongo, Rulo, Moroca, Chamaluco. It is now known to be susceptible to *Fusarium* wilt (*F. oxysporum* f. *cubense* Race 2), (STOVER and WAITE, 1960), and it is this disease that has probably given rise to 'Moko disease' reports from Haiti and some other places.

‡ Considered in Venezuela to have some field resistance.

Figure 9. Known distribution of (Moko) bacterial wilt of bananas. Arrows indicate possible routes of dissemination

The presence of the disease in Honduras and on the Caribbean coast of Panama is believed to have followed introduction of planting material from areas already having Moko disease. The probable routes of dissemination indicated (*Figure 9*) are based on the evidence that the disease first appeared in farms following planting of rhizomes from Venezuela, Costa Rica or

Figure 10. World-wide distribution of Pseudomonas solanacearum. *Modified after* Dowson (1949) *and* Kelman (1953)

Panama, and has largely remained confined to those farms. Moreover, bananas had previously been grown in Honduras and northern Panama for many years without the appearance of bacterial wilt.

Isolates obtained from diseased banana plants from each of the countries where the disease occurs have recently been tested for pathogenicity to young field-grown 'Gros Michel' bananas. Some isolates differed in symptomatology and virulence to bananas, but no consistent differences were detected for isolates from any given area. Highly pathogenic isolates with similar cultural characteristics were obtained from each country. All of the isolates fell within the range of pathogenic variation previously noted for the banana strain of *P. solanacearum* (BUDDENHAGEN, 1960). It is especially interesting to compare the limited known distribution of bacterial wilt of bananas (*Figure 9*) with the world-wide distribution of bacterial wilt of solanaceous crops caused by the solanaceous strain of *P. solanacearum*, *Figure 10*. It is recognized that the lack of detailed studies in Asia and Africa and also in parts of the tropics of the Western Hemisphere may be in part responsible for the apparent limited distribution of Moko disease.

CURRENT STATUS OF THE DISEASE

Trinidad

Moko disease is the limiting factor in banana production in some areas of Trinidad. The disease is serious in plantations of 'Lacatan' bananas in southeastern Trinidad on land recently cleared from *Mora* forest. Even though tool disinfection is practised and diseased plants are eradicated, the disease is severe. Many clumps of *Heliconia* spp. growing nearby in the forest were diseased, and some cultures of the pathogen were obtained from selected plants. This is a hilly area of tropical rain forest. Soil is an acid heavy clay. The early history and observations of the disease on Trinidad plus the present observations indicate that the disease has been present on *Heliconia* spp. growing in the jungle and that bananas subsequently planted on jungle-cleared land became infected from this source.

British Guiana

Moko disease is the limiting factor in banana and plantain production in British Guiana. It occurs generally wherever *Musa* are planted along the rivers. Along the Essequibo river, diseased plantains were observed growing on a waterlogged silty clay. Plants of *Heliconia psittacorum* growing near the plantains were also affected and the pathogen was recovered from them. This area receives about 100 in. of rain annually and has high humidity and temperature. The long-standing presence of the disease plus the present observations indicate that the disease is probably indigenous generally in British Guiana.

Venezuela

Moko disease is the limiting factor in banana production in parts of Venezuela. It was observed in the Yaraquí valley on several varieties growing on a rich river silt loam of pH 7 to 8. Although the abundant *Heliconias* in this area were not observed to be diseased, observations were limited. Rainfall is about 80 to 100 in. annually and conditions are

tropical. It is considered by growers that both 'French Plantains' and 'Dwarf Cavendish' bananas are partially resistant and may be grown where 'Gros Michel', the 'Apple' banana, or 'Chato' plantain cannot be grown due to disease severity. Moko disease was also observed on 'Dwarf Cavendish' growing near Lake Valencia in the state of Aragua. Conditions there are not strictly tropical since temperatures and humidity are not constantly high, soil is an alkaline lake silt, and rainfall is only 30 to 40 in. annually. No Heliconias were observed; the valley supports crops such as cotton, beans and tomatoes. Apparently bananas and the 'Chato' plantain are occasionally diseased at scattered locations in much of Venezuela. These areas differ considerably from the 'ideal picture' of endemic Moko areas with recently cleared jungle lands of tropical rain forest and heavy, poorly drained soils. To what extent disease distribution may be attributed to planting of diseased stock in these areas is unknown.

Southwestern Costa Rica and adjacent Panama

Moko disease is severe in much of the area along the Pacific coast, having already destroyed over 1 million plants (ANON., 1959). The adoption of rigid sanitation practices is now limiting somewhat the spread of the disease. The presence of the disease on *Heliconia* spp. in virgin jungle has been reported (SEQUEIRA, 1960), and their abundance assures a continuing Moko problem. Soils in general are relatively poorly drained with a pH of 6 to 6·5. Rainfall is very high, up to 200 in. annually, and conditions are those of a tropical rain forest with high humidity and temperature.

North Caribbean coast of Panama

Moko disease is largely limited to farms planted with rhizomes from the Pacific coast of Panama or Costa Rica where the disease was present originally. Environmental conditions do not differ considerably from those areas except that rainfall averages about 100 in. annually and mean temperatures are slightly lower. Spread of Moko disease in the area has been rapid where precautions to prevent spread were not observed.

Honduras

Moko disease is limited to farms planted with Costa Rican or Venezuelan seed and incidence in 1959 was limited to approximately 80 000 cases. Spread has been rapid where precautions were not taken but at present the disease is under control with a low continuing incidence. Annual rainfall is about 50 in., soils are silt loams to silt clays, generally well drained. A winter season occurs with temperatures occasionally dropping to the low 60s (°F) and rarely to the 50s. Thus, conditions are somewhat less tropical than most of the other areas and resemble the Lake Valencia area of Venezuela in the low rainfall and cooler seasonal temperature. Heliconias are present in some areas but are not generally abundant. Where they are present they have not been found to be diseased.

DISCUSSION

Diseased indigenous *Heliconia* spp. have apparently been involved in the subsequent appearance of banana wilt in Costa Rica (SEQUEIRA, 1960) and

Trinidad. They are probably similarly involved in British Guiana, although their presence in jungle lands there has not been recorded. Thus, where bananas have been planted on land cleared from jungle containing diseased Heliconias, the bananas have been attacked. However, the distribution of several species of susceptible *Heliconia* extends beyond the range of bacterial wilt of bananas, ranging from Brazil to Mexico. Moreover, some species apparently are also present in parts of southeastern Asia (LANE, 1955). Bananas have been grown in many areas where Heliconias occur without becoming affected by the disease. It is possible that Heliconias affected by bacterial wilt are present in many areas where bananas have not yet been planted, or where the incidence of the disease in Heliconias is too low to result in its subsequent appearance in bananas. There also must be other factors, at present unknown, that are responsible for the distribution of bacterial wilt of bananas and Heliconias. Certain similarities exist among the infested areas of Trinidad, British Guiana and Costa Rica:

(*1*) Heliconias are abundant although the species differ.
(*2*) Soils in general are heavy, clay or clay loams of acid pH.
(3) Rainfall is high—100 to 200 in. annually.
(*4*) Temperature and humidity are high—those of a tropical rain forest area.
(5) The solanaceous strain of *P. solanacearum* is present.

These similarities are also typical, however, of areas where no Moko disease is known, such as Surinam, and the north coast of Panama, where the disease is believed to have been absent until its recent introduction on seed. Parts of Venezuela where the disease is present differ in the absence of one or more of the above conditions. Thus, the reasons for disease distribution in parts of Venezuela, and absence of the disease from other apparently suitable areas, remains unexplained. In general, however, banana areas in Ecuador, Colombia and the Antilles where the disease has not been confirmed differ considerably from the Moko areas of Trinidad, British Guiana and Costa Rica, and lack several of the conditions listed. Lower rainfall and well drained volcanic soils are typical of some of these areas, and Heliconias are either not abundant, or gradually disappear as in some of the Antilles of the northern Caribbean.

SUMMARY

The known range of bacterial wilt of bananas is more limited than reports in the literature would indicate. The disease is believed to be restricted to six countries in South and Central America. In Costa Rica, Trinidad, British Guiana and Venezuela it is one of the main limiting factors in banana and plantain production. The symptomatology of the disease is described to aid in the accurate detection of the disease in new areas. The known history of the disease on bananas is critically reviewed and factors believed to account in part for its distribution are discussed.

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Shade and Fertilizer Relations in the Banana

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The response of certain tropical and semi-tropical crops to fertilizer applications is markedly affected by the presence or otherwise of shade trees. The existence of an interaction between shade and nutrition in the growth of cacao has been shown by Murray (1954), in tea by Wight (1958), and in coffee by a considerable amount of indirect evidence. Accordingly when a further shade experiment was planned for cacao it was decided to investigate the relationships for coffee and the banana as well.

Although the banana as a crop is nearly always grown in full light, it is sometimes grown in a mixed stand, under coconuts for example. Also the suckers arising at the base of the parent plant are shaded very considerably until the parent plant has produced its bunch and been cut down. Little is known of the effect of such shading on the early development of the young plant. Furthermore, self-shading is a factor that will be concerned in the spacing of the crop.

EXPERIMENTAL DETAILS

The experimental site was the Las Hermanas sub-station of the Regional Research Centre. The soil is an acid heavy clay, pH 4·5 to 5·0, that suffers from impeded drainage in the wet season and may crack badly in a pronounced dry season. As a result it would not be considered a very suitable soil for either cacao or bananas, but this soil type has supported cacao in the past and in fact the land was cleared from old cacao and Erythrina shade trees in preparation for the experiment.

After ploughing and harrowing in the dry season of 1958 the land was made up into cambered beds with surface drains between, the distance between drains being 20 ft, centre to centre. The shade treatments were 20, 50, 70 and 100 per cent of full light and were created by suspending Saran mesh of the requisite density on wires slung from teak poles. Within each light intensity all combinations of nitrogen (N), phosphorus (P) and potassium (K) were to be compared together with a foliar application of a complete NPK spray.

The experiment was designed primarily for cacao but at the spacing of 10 ft used for the cacao some considerable time would elapse before the cacao plants would meet and this gave the opportunity of putting in bananas as a temporary crop between the cacao. As a result the banana spacing, 20 ft, bore no relation to field practice and each stool might be considered as growing in isolation since the cacao plants for this first year were very small. The layout comprised two randomized blocks of four sub-blocks for the four shade treatments, each sub-block containing five plots for the fertilizer

treatments with the high order interactions confounded. Each treatment plot carried two banana stools.

As planting material the Dwarf Cavendish was used so that the overhead shade at 14 ft would not restrict growth. Planting was done on 19 June 1958 when the rains were well established. At the time of planting, each planting hole received about 20 lb of composted sawdust and 4 oz of ammonium sulphate, and those treatments receiving phosphorus, 8 oz of superphosphate. Subsequent fertilizer applications were made of 2 oz each of ammonium sulphate, superphosphate and muriate of potash four weeks after planting and every three months subsequently. Ammonium sulphate only at the same rate was applied to nitrogen plots between the three-monthly applications so that nitrogen treatments were receiving fertilizer every six weeks. The foliar spray was a 0·5 per cent solution of a proprietary mixture—Davgro—and this was given fortnightly. Cultural operations involved normal weeding as required and a three-weekly spray of Perenox for leaf spot control. Once the stools had matured their bunches they were destroyed, as continued growth would have interfered with the development of the cacao. This limited results therefore to the plant crop only.

GROWTH MEASUREMENTS

At three-monthly intervals counts were made of the number of leaves produced per plant and the number that were senescent. No significant differences were found between shade or fertilizer treatments, and the means for the shade treatments only are given in *Table 1.*

Table 1. Leaf production

Light as % sunlight	*No. of leaves produced*		*Healthy leaves at 6 months*
	up to 3 months	*up to 6 months*	
20	11·8	22·3	14·3
50	12·0	23·9	15·0
70	11·7	24·0	14·8
100	12·2	23·6	14·5

The absence of any treatment effects under such a wide range of both fertilizers and light intensities seems remarkable. Differences in respect to shade were visible to the eye, the leaves under the heaviest shade being much darker green than the less heavily shaded plants. Moreover, rather than being etiolated the heavily shaded plants were shorter and more compressed than the plants growing at the higher light intensities. Growth in all treatments was good, as evidenced by a rate of leaf production of almost one per week (SIMMONDS, 1959).

Some of the plants shot their bunches soon after the six-month leaf count so that later comparisons of leaf production were not possible.

YIELDS

The first bunch shot some six months from planting and as the bunches matured they were harvested at the three quarters full stage and bunch weight and number of hands recorded. The average bunch weight is given in *Table 2.* These yields may be considered very good under the particular soil and climatic conditions.

Table 2. Average bunch weight (lb): means for two plants

Treatments	*Light as % sunlight*				*Mean*
	20	50	70	100	
Control	41	55	46	41	46·0
N	46	65	42	49	57·6
P	47	60	46	58	47·6
K	44	56	45	49	48·9
NP	40	65	51	61	49·0
NK	42	59	60	42	51·0
PK	41	33	60	43	44·5
NPK	60	54	63	46	55·9
NPK†	46	60	67	56	57·0
Mean	45·3	56·8	54·9	50·2	50·8

NPK† denotes foliar spray.

Largely as a result of the high variability with only two plants per plot none of the treatment effects proved statistically significant. There are indications from the table that the fertilizers have had some effect with the foliar spray treatment giving the highest yield but it seems remarkable that shading down to as low a light intensity as 20 per cent of full light has had such little effect on the final weight of the bunch.

It must be appreciated, however, that this is related to the longer time taken for a bunch to mature under shade. Obviously the economically important value for yield must take this into consideration and yields have also been calculated on the basis of weight of bunch produced per month of growth from planting to harvesting.

Again these results just fail to reach the 5 per cent level of significance and in *Table 3* only the means for shade treatments are given.

Table 3. Months to harvest and weight of bunch produced per month of growth

Light as % sunlight	20	50	70	100
Months to harvest	13·5	11·1	10·7	10·4
Average weight lb/bunch per month	3·4	5·1	5·1	4·8

The time to harvesting and the average rate of production of bunch per month are plotted in *Figure 1* and would indicate little change in rate of bunch production with shading down to 50 per cent of full light. Although the falling off at the lowest light intensity is not statistically significant, it would appear to be real.

As regards the lack of fertilizer response, SUMMERVILLE (1944) has claimed that mineral supplies in regard to fruit production are only effective during the first three months of growth of the stool. It is therefore probable that during that period no nutrient was in such short supply as to have any appreciable effect on fruit production. Had the stools been allowed to sucker and produce a ratoon crop it is possible that fertilizer responses might then have been secured but as has been stated the layout of the experiment did not permit this.

This absence of any effect of shading down to 50 per cent would appear in conflict with field observation and reasons must be sought. The wide spacing must be one factor for at a normal field spacing there would be a pronounced mutual shading effect between plants.

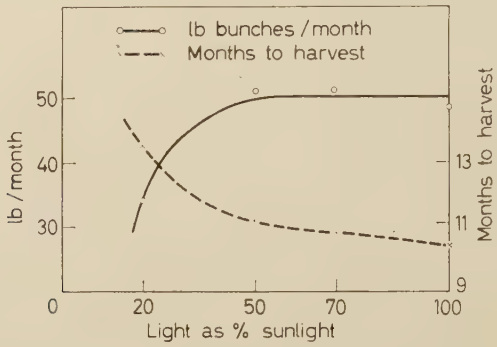

Figure 1. Months to harvest and weight of bunch produced per month of growth in relation to light intensity

The effective incident light, however, is extremely difficult to measure and it would not be profitable at this stage to discuss any further the relative effect of overhead and lateral shading. Another possible factor, however, may be wind. Under the shade, both overhead and lateral, of the Saran material the plants were far less subject to the prevailing wind than the plants in full light. The leaves on these latter were much shredded and this may have resulted in some depression of yield in full light.

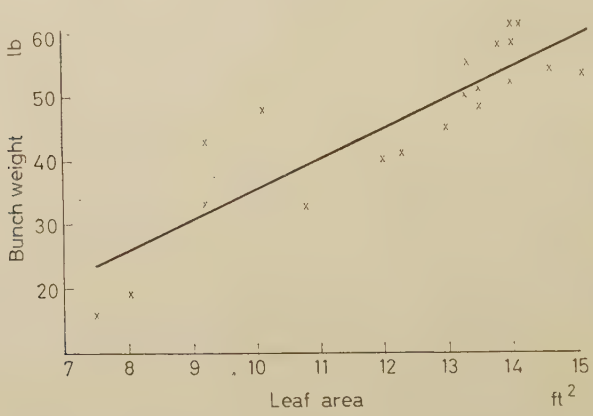

Figure 2. Bunch weight in relation to area of third leaf at six months

LEAF AREA AND BUNCH WEIGHT

When samples for leaf analysis were taken from the third leaf from the apex at six months the length and breadth of this leaf were recorded. The product of these two measurements can be used as a measure of the area of the leaf. When this parameter, termed for convenience leaf area, is plotted against final bunch weight, *Figure 2*, for plants in full light, a close

relationship is seen to exist. The correlation coefficients for each light intensity constitute *Table 4*.

For each light intensity the correlation coefficient proved significant and the overall coefficient was 0·75. The chi squared test showed the difference between the coefficients for full light and the heaviest shade to be significant.

Table 4. Correlations and regression equations for yield and area of third leaf

Light as % sunlight	*Correlation coefficient*	*Regression*
100	0·87	$Y=4{\cdot}8\ X-12{\cdot}5$
70	0·75	$Y=5{\cdot}4\ X-17{\cdot}5$
50	0·81	$Y=4{\cdot}7\ X-\ 5{\cdot}3$
20	0·62	$Y=2{\cdot}9\ X+18{\cdot}2$

Y denotes bunch weight (lb).
X denotes leaf area parameter (length × breadth, ft²).

SUMMERVILLE (1944) has used a concept, *Ts*, made up by combining total leaf area, length of day and mean temperature, and found a correlation of 0·59 with yield expressed as number of fruit. Under his conditions, however, climatic variation especially of temperature was far more marked and the calculation of *Ts* involves considerable labour. In comparison the relation here presented is very easily found.

SIMMONDS (1959) quotes various other growth correlations but these will not be discussed here. The conclusion may be drawn, however, that the size of the third leaf at six months very largely determines the weight of the final crop stressing the importance of securing rapid early growth in the crop. Any treatment, either cultural or fertilizer, after this stage is unlikely to have much effect on the weight of the bunch. This of course applies only to the plant crop.

LEAF ANALYSIS

At six months, leaf samples were taken from all plants for analysis. Counting the spear leaf as No. 1, provided that more than 12 in. had emerged, leaf No. 3 was sampled taking material from the mid section on either side of the mid rib. The third leaf was used by HEWITT (1955) and previous work by MURRAY (1960) confirmed this as a satisfactory choice.

After oven drying, the material was analysed for nitrogen, phosphorus, potassium, calcium and magnesium. The effect of shading on water and ash content is shown in *Figures 3* and *4*. There is an obvious linear relationship of increasing water and ash content with shading down to 20 per cent light. These results agree with those for cacao and the differences proved significant at $P=0{\cdot}05$. The differences due to fertilizers were not significant nor were any interactions.

The results of the mineral analyses are given in Appendix I. No differences proved statistically significant largely as a result of the high plant to plant variability. The means show in general some small effects from the individual fertilizers and for certain of the nutrients a shading effect

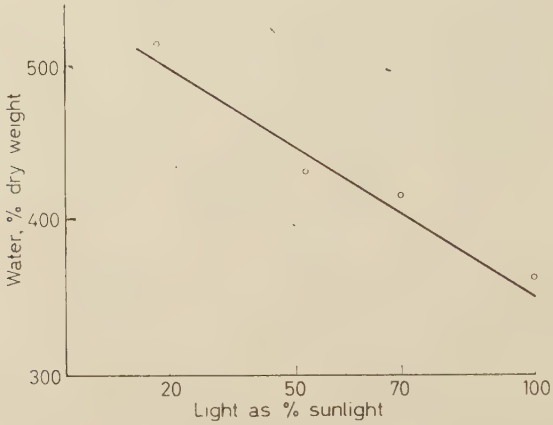

Figure 3. Water content of leaf in relation to light intensity

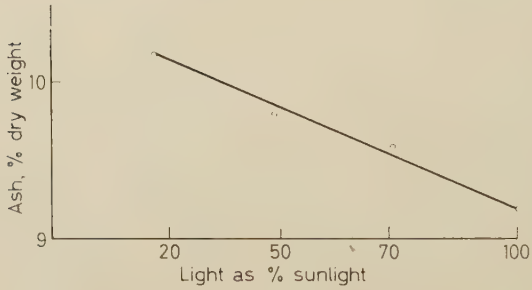

Figure 4. Ash content of leaf in relation to light intensity

does appear. This is shown in *Figures 5* to *9*, where the means for all treatments at each light intensity are plotted.

There is only a small change in percentage leaf nitrogen as a result of shading but a marked accumulation occurs for percentage of phosphorus. The same is true for percentage of potassium.

The results for calcium must be viewed with some caution as difficulties were experienced in the analytical technique and high variability was found. It would appear, however, that for neither calcium nor magnesium is there any appreciable accumulation with shade. Since both these nutrients tend to be present at a low level in young leaves, and increase with age, samples from older leaves might have shown rather better any changes with shade.

In interpreting the results of leaf analysis it is often more profitable to examine ratios rather than actual values. Had there been significant differences in yield an attempt could have been made to relate yield both to percentage contents of the various nutrients and to ratios. In the absence of such differences, however, such an examination would be of little value.

MURRAY (1960) has given a provisional table of levels of adequacy and severe deficiency drawn up partly from studies in sand culture. The

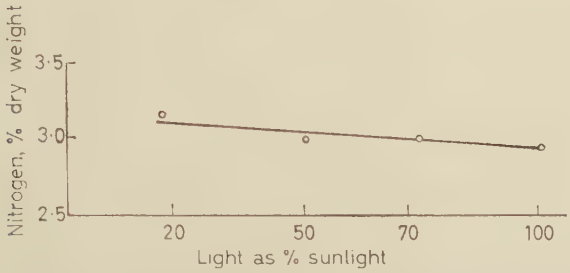

Figure 5. Nitrogen content of leaf as percentage dry weight in relation to light intensity

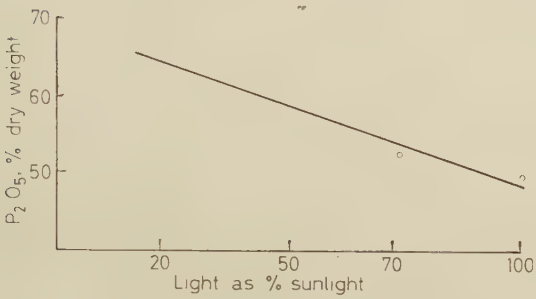

Figure 6. Phosphorus content of leaf as percentage dry weight in relation to light intensity

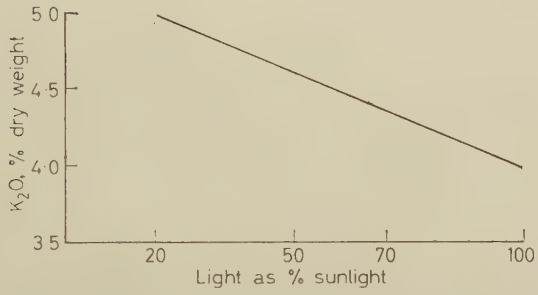

Figure 7. Potassium content of leaf as percentage dry weight in relation to light intensity

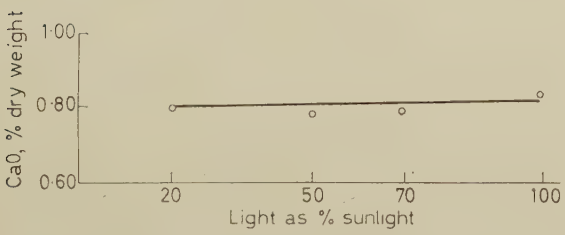

Figure 8. Calcium content of leaf as percentage dry weight in relation to light intensity

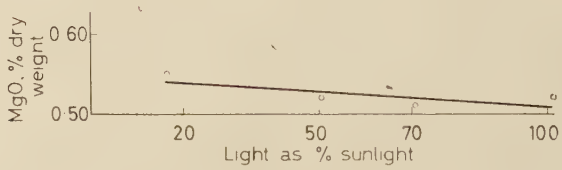

Figure 9. Magnesium content of leaf as percentage dry weight in relation to light intensity

mean levels here recorded for all nutrients with the exception of calcium fall in the region of adequacy so that it is perhaps not surprising that on this soil fertilizers have had no effect on yield, certainly for the plant crop. The calcium levels are low but since there was no visual sign of deficiency whatsoever this may be merely a reflection of the acidic character of the soil.

CONCLUSION

It would appear from this experiment that yields of the banana are less affected by shade than is usually thought. However, the limitations of the experiment, viz. only a plant crop from two stools per treatment, were such that too great emphasis cannot be laid on this point. Of more significance perhaps is the fact that shade plays the same nutrient-sparing role in the banana as it does in cacao.

Leaf analysis shows levels of nitrogen, phosphorus and potassium in leaves of plants growing under shaded conditions higher than those growing in full light. This is to be expected if shade slows down the general metabolism of the plant and in particular the production of carbohydrates.

When the banana is grown in a mixed stand under some degree of shade a delay in maturing of bunches is to be expected but there is also less likelihood of mineral deficiencies arising. It would therefore be expected to tolerate rather infertile soils rather better under such shaded conditions. On fertile soils or with the use of fertilizers, however, the most rapid and early development of bunches would be secured in full light.

SUMMARY

A field experiment is described in which Dwarf Cavendish bananas were grown at four light intensities ranging from full light down to 20 per cent of full sunlight, with applications of nitrogen, phosphorus and potassium in all combinations at each light intensity. A foliar spray treatment was included.

Neither fertilizers nor shading had any significant effect on rate of leaf production up to six months. Nor was there any effect on final yield, though when allowance was made for the delay in maturity with shading a falling-off in yield under the heaviest shade was found.

A highly significant correlation was shown to exist between the product of the length and breadth of the third leaf at six months of age and the final weight of bunch. Field practice should therefore aim at giving the sucker a rapid early start.

Leaf analyses were carried out and indicated that shade led to increased levels of nitrogen, phosphorus and potassium in the leaf. There was little

effect of shade on calcium or magnesium levels. In the absence of any yield responses to the fertilizers no attempt could be made to relate yield to nutrient levels in the leaf.

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APPENDIX I

ANALYSES OF THIRD LEAF MEANS FOR TWO PLANTS, EXPRESSED AS PERCENTAGE DRY WEIGHT

Nitrogen given as percentage dry weight, light as percentage sunlight

Light	20	50	70	100	*Mean*
Control	3·12	2·82	2·97	3·01	2·98
N	3·14	3·05	3·01	3·17	3·10
P	3·04	3·05	3·02	2·95	3·01
K	3·13	2·71	3·09	2·85	2·95
NP	3·18	3·14	3·08	3·16	3·14
NK	3·18	3·18	3·01	3·10	3·14
PK	3·05	2·84	2·88	2·63	2·85
NPK	3·00	3·07	3·05	2·87	3·00
NPK†	3·22	3·09	3·12	3·17	3·15
Mean	3·11	2·99	3·02	2·99	3·03

Phosphorus pentoxide as percentage dry weight, light as percentage sunlight

Light	20	50	70	100	*Mean*
Control	0·59	0·52	0·53	0·48	0·53
N	0·56	0·57	0·50	0·50	0·53
P	0·87	0·62	0·52	0·48	0·62
K	0·61	0·55	0·49	0·46	0·53
NP	0·60	0·62	0·58	0·56	0·58
NK	0·57	0·54	0·53	0·50	0·53
PK	0·70	0·55	0·58	0·57	0·60
NPK	0·69	0·56	0·59	0·47	0·58
NPK†	0·69	0·58	0·53	0·50	0·58
Mean	0·66	0·57	0·53	0·50	0·57

Potassium oxide as percentage dry weight, light as percentage sunlight

Light	20	50	70	100	*Mean*
Control	4·65	4·50	4·45	3·40	4·22
N	4·80	4·35	3·95	4·20	4·31
P	5·10	4·50	4·15	4·10	4·44
K	5·15	4·75	4·35	4·10	4·38
NP	4·25	4·60	4·65	3·65	4·22
NK	4·75	4·62	4·65	4·00	4·44
PK	5·10	5·10	4·95	4·00	4·50
NPK	5·52	4·85	4·35	4·10	4·45
NPK†	5·35	4·70	4·45	4·15	4·50
Mean	4·74	4·58	4·35	3·91	4·40

Magnesium oxide as percentage dry weight, light as percentage sunlight

Light	20	50	70	100	*Mean*
Control	0·56	0·50	0·55	0·56	0·54
N	0·50	0·52	0·56	0·56	0·53
P	0·51	0·53	0·46	0·61	0·53
K	0·57	0·50	0·49	0·46	0·50
NP	0·59	0·56	0·55	0·53	0·56
NK	0·54	0·48	0·40	0·41	0·46
PK	0·54	0·49	0·50	0·50	0·50
NPK	0·56	0·54	0·51	0·50	0·53
NPK†	0·60	0·56	0·55	0·58	0·57
Mean	0·55	0·52	0·51	0·52	0·52

The Assessment of Black Pod Disease Control in Cocoa by Mistblowing

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Black Pod disease, *Phytophthora palmivora* (Butler) Butler, is without doubt the most serious fungal disease of cacao in West Africa at the present time, and in certain parts may attain such proportions that the crop is lost year after year. It is not surprising, therefore, that the disease is receiving much attention from the cacao producers, marketing authorities and commercial firms selling fungicides and spraying equipment.

With the increase in acreage planted and the planting of higher yielding material it is most necessary to obtain some idea of (*a*) the losses that are inevitable and (*b*) those losses that might be avoided by use of better control measures. This can only be achieved by a careful assessment of the yields of previous years and the losses in conjunction with the environmental factors. In this particular paper some of these factors are mentioned even if only briefly, but it is hoped that shortcomings in this direction are offset by the value of accurate crop records kept during five years of small volume copper fungicidal spraying.

METHODS

The area referred to in this paper has a double use in that the primary purpose of the yield recording is to obtain improved material for planting, but it also serves to provide data for the assessment of Black Pod disease. It consisted of some 500 trees, with occasional reductions by root disease, on a level, uniform, fertile, young volcanic soil at Tombel in the Kumba Division of the Southern Cameroons. The area is part of an estate where Black Pod disease is controlled by mistblowing 3 lb of a proprietary copper fungicide in 15 gallons of water (Sanders, 1956). Usually the spraying cycles were timed to coincide with the crop and sometimes the cycle length varied, but generally there were ten cycles per annum.

Yield records of individual trees were made weekly but cherelles of less than three inches length lost because of Black Pod disease were not recorded. Academically it is of interest to record pods rejected for Black Pod and pods partially attacked but commercially it is the losses that matter, consequently the terms ' losses ' or ' Black Pod incidence ' in the text refer to pods actually rejected.

The year in the terms of this paper extends from 1 April to 31 March.

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ENVIRONMENTAL FACTORS AFFECTING DISEASE INCIDENCE

(1) *Climate*

TOLLENAAR (1958) considered that a high humidity when combined with a temperature of 20°C and lower favoured sporulation. Experiments with inoculated pods in the laboratory indicated that it is the actual water content of the air that is of prime importance, but that the upper temperature limit for sporulation in a favourable humidity was 28·9°C (PRICE, 1958).

Humidity is to a large extent dependent upon rainfall and at Tombel the peak rainy season occurs during August. In *Table 1* the rainfall, rainy days, total yield and reject pods are given for the selection area during 1959.

Table 1

Month	*Rainfall*	*Rainy days*	*Pods*	*Rejects*
Jan	4·1	10	533	119
Feb	1·4	8	67	24
Mar	9·6	18	50	25
Apr	9·1	18	125	49
May	11·8	18	335	44
Jun	12·1	24	2 041	369
Jul	15·7	24	5 235	507
Aug	19·3	25	6 715	1 140
Sep	18·7	29	3 169	1 055
Oct	19·0	25	3 864	318
Nov	6·2	16	2 580	62
Dec	0·6	6	1 978	14
		Totals	26 692	3 726

From *Table 1* it will be noted that there appears to be a relationship between yield, rainfall and losses through Black Pod disease. Analysis of the data showed that yield and loss, and rainfall and loss were positively correlated, but as it is unlikely that rainfall could appreciably affect the losses during the same month, only the former correlation of yield and loss is considered to be important.

The correlation coefficient for this relationship was +0·782, which although highly significant, is a lower value than expected and may indicate heterogeneous monthly variations in the rate of infection.

That this variation takes place is demonstrated using the chi squared test assuming an average rate of infection based upon the annual production and loss. The chi squared value is 1 725·10, which with 11 degrees of freedom is highly significant.

The monthly deviations from the average expected loss and percentage infection are given in *Table 2*.

It will be observed that the positive deviations, indicative of a higher rate of infection than expected, tend to occur during the first half of the year. During 1959 spraying against Black Pod disease commenced in February with cycles of three weeks followed by four two-weekly cycles during April and May, and then three-weekly cycles. This should have ensured that the bulk of the crop was protected right through the cherelle stage to maturity. In retrospect, it would seem that the level of potential infection was already high when spraying commenced and that several cycles of spraying were required before control was gained.

Table 2

Month	*Reject pods, deviation from expectation*		*Black Pod* %	*Production* %
Jan	+	74·40	22·3	2
Feb	+	14·65	35·8	0
Mar	+	18·02	50·0	0
Apr	+	31·55	39·2	1
May	—	2·76	13·1	1
Jun	+	84·09	18·1	8
Jul	—	223·76	9·7	20
Aug	+	202·64	17·0	25
Sep	+	612·60	33·3	12
Oct	—	221·38	8·2	14
Nov	—	292·15	2·4	10
Dec	—	262·11	0·7	7

Another important conclusion to be drawn from *Table 1* is that the climate favours Black Pod disease throughout much of the year and it would be of little use to plant a variety or type with different cropping periods to effect control by ' escape '.

This relationship, although demonstrated with results from 1959, was shown earlier by SANDERS in 1957 who concluded that in a ' wet year ', i.e. 1956–57, the precipitation was always in excess of evaporation between February and November.

When mistblowing began in 1954 the canopy of the cacao trees was very poor and presented the typical appearance of ' Leafless Twig ' condition so common in West Africa. It was possible to find on almost any tree selected at random Psyllids, Jassids, Capsid damage and *Cephaleuros*, and several people suggested that these coupled with unavoidable neglect during 1939–45 were sufficient to cause the poor appearance of the canopy. It became apparent after one season of mistblowing that the canopy was improving and COUTTS (1958) on account of this improvement suspected that *Phytophthora* might have been playing a considerable part in reducing the leaf canopy. He was able to demonstrate with ease that *Phytophthora* did infect young leaves to produce what is now termed ' Tip Necrosis '. The degree of damage to young leaves is determined by their age at infection and at Tombel it is possible to lose a whole flush with disastrous consequences, for not only is there no extension growth, but since flushing takes place during the dry season, when there is no spraying, and the early rains, there is a considerable potential of inoculum present as the cherelles form. Normally spraying would not be considered by a planter until pods and cherelles appear and by that time there may be a considerable degree of infection present. It is clear that spraying should commence prior to the deposition of sporangia on the pods, or their formation on young leaves.

One further complication in the interpretation of the results is that the 30-year old trees varied considerably from year to year in their yield. This was partly due to the variable climate throughout the year and partly to the amount of rainfall during the dry season.

The dry season may be considered to extend from December until February (*Table 3*).

The canopy improved so much during the first three years of mistblowing that it came as a shock to see defoliation taking place during March 1959,

but because of illness the pathologist (D.P.) was unable to determine the exact cause although *Phytophthora* damage was suspected. In 1960, however, when the leaf fall commenced trees were examined and it was realized that all the young flushes were attacked to a greater or lesser extent by *Phytophthora* whilst many of the older leaves were shed, presumably because of drought. Instead of the normal three flushes on the branches these were reduced to two or even one.

Table 3. Dry season rainfall at Tombel (in.)

Month	1956–57	1957–58	1958–59	1959–60
Nov	5·19 (8)*	8·34 (21)	9·36 (15)	6·19 (16)
Dec	1·71 (4)	5·33 (13)	0·99 (7)	0·61 (6)
Jan	4·58 (6)	0·69 (4)	4·12 (10)	1·58 (3)
Feb	3·29 (5)	3·70 (5)	1·42 (8)	4·67 (10)
Mar	15·46 (12)	7·71 (16)	9·56 (17)	13·15 (18)

* The number of rainy days is given in parentheses.

(2) *Inoculum potential*

THOROLD (1953) has shown that the percentage of Black Pod is larger, the larger the number of pods per tree. Hence, a tree with 50 pods will have a larger percentage of Black Pod than a tree with only 2 pods. This relationship is also apparent in Tombel and was as given in *Table 4* in 1955–56.

Table 4. Incidence of Black Pod 1955–56

Pods/tree	20	40	60	80	100
Black Pods, %	7	15	18	19	20

In trying to assess the efficiency of a spraying programme on a plantation basis in one particular year or rather in different years with varying yields, the main difficulty is to find a basis for comparison.

Moreover, it is obvious that a tree with say 10 pods/tree surrounded by trees with on the average say 50 pods/tree, will have a smaller chance to escape infection than the same tree surrounded by trees with on the average 1 pod/tree.

In a plantation, there will always be a large variation in the number of pods on any one tree at any moment. Consequently, the Black Pod incidence on a certain tree is not only a function of the number of pods it is carrying, but also of the numbers of pods carried by the whole population of which it is a member.

At this stage, it was decided rather than to try to assess the efficiency of the spray programme on the basis of the Black Pod incidence on individual trees, as worked out by Thorold, to base it on a population of trees, in this case the 500 trees comprising the population. It was assumed therefore that a population of trees with a mean yield of 20 pods/tree would have a relatively lower percentage of Black Pod incidence than a population with a mean yield of 40 or 60 pods/tree, as shown in the following hypothetical example:

The following linear relationship between pods/tree and % Black Pod is assumed.

Pods/tree:	20	40	60
% Black Pod:	7	15	18

Then assume two populations of trees of 500 trees each:

Pods/tree	20	40	*Total*
No. of trees	500	500	1 000
% Black Pod	7	15	—
Total No. of Pods	10 000	20 000	30 000
Total No. of Black Pods	700	3 000	3 700
Mean % Black Pod	—	—	12·3

Consider now an area with the same disease potential but with 20 pods/tree more, or assume the same area a year later with an increased production level of 20 pods/tree, but with the same original infection level. The yields and losses become:

No. of pods/tree	40	60	*Total*
No. of trees	500	500	1 000
% Black Pod	15	18	—
Total No. of Pods	20 000	30 000	50 000
Total No. Black Pod	3 000	5 400	8 400
Mean % Black Pod	—	—	16·8

This example shows that the substitution of individual trees by populations of trees is merely a logical consequence of the observations made by Thorold.

In Tombel the production levels shown in *Table 5* were obtained in the area under consideration.

Table 5

Season	*Mean No. Pods/tree*	*Mean Black Pods*
1955–56	50	8·3
1956–57	59	11·6
1957–58	83	12·7
1958–59	82	18·8
1959–60	55	7·7

It was found that a population with a mean number of pods/tree of 50 in 1955–56 had a mean number of Black Pods of about 8. This average of 8 Black Pods/tree is the resultant of the number of pods on each tree in the population and the integrated effect of the number of pods on each of the surrounding trees in the population. Within this population with a mean number of 50 pods/tree having an average number of 8 Black Pods, there appeared to be a highly significant correlation between the numbers of pods and Black Pods of the individual members of this population. This relationship may be expressed as follows

$y=0{\cdot}23x-3{\cdot}2$ (see *Figure 1* for 1955–56)

The regression equations for the successive years were as follows:

1956–57 : $y=0{\cdot}24\ x-2{\cdot}6$

1957–58 : $y=0{\cdot}23\ x-6{\cdot}4$

1958–59 : $y=0{\cdot}26\ x+2{\cdot}5$

1959–60 : $y=0{\cdot}22\ x-4{\cdot}4$

The individual regression coefficients were all highly significant ($P=0{\cdot}01$) but the difference between them was not significant. Therefore, the tangents of the slopes of the regression lines may be considered to be the same (this

point will be dealt with later) and are taken as 0·23. This means that within the population the relative rate of increase of infection with increasing numbers of pods/tree is the same for the different years and consequently for different production levels, that is between 50 and 83 pods/tree per annum on the average.

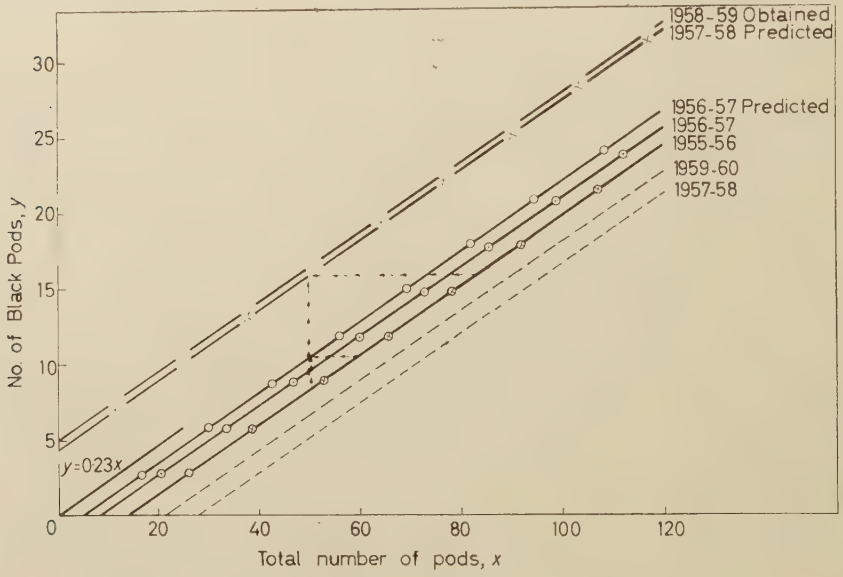

Figure 1. Black Pods as a function of total pods

As a result of this parallelism, the rate of infection can be predicted for a certain yield, as long as the initial level of infection in any one production year is known.

Taking 1955–56 as the basis for comparison, and assuming the spraying programme would be equally efficient as in 1955–56, the rate of infection in 1958 (at a mean yield of 83 pods/tree) could have been predicted (cf. *Figure 1*). It will be seen from the graph that it is 23 Black Pods for a tree bearing 83 pods. The actual rate of infection in 1958 is represented by the equation $y=0{\cdot}23\,x-6{\cdot}4$, hence at a very much lower level than predicted, viz. a tree with 83 pods had only 13 Black Pods. The conclusion that can be drawn from this, is that the spraying programme in 1958 was much more efficient than that in 1956, assuming both years had the same initial level of infection.

The same reasoning holds true for 1956–57. It will be seen from *Figure 1* that the predicted losses in 1956–57 assuming the same infection level as in 1955–56 were slightly higher than actually obtained.

Hence, since the initiation of the spray programme, its efficiency increased year by year and reached a maximum in the 1957–58 season.

It could be argued, however, that owing to the integrated effect of successive spraying years the potential level of infection was reduced. This would then—at least in part—account for the greater efficiency of the

spraying in successive years up to 1957–58. Expressed differently, the intercept on the y axis is a measure of the potential infection level.

If the regression line intercepts the negative part of the y axis the potential level of infection is lower than when it crosses the positive part of the y axis. Referring to the graph it indeed appears that larger negative values at the intercept with the y axis were obtained in the period 1955–56 to 1957–58.

In 1958–59, however, the positive part of the y axis was intercepted, meaning that for whatever reason the level of infection increased considerably after the 1957–58 season.

An explanation of the sudden breakdown in the control of Black Pod disease may be this. It was observed that in the period 1955–56 to 1957–58 there was a remarkable improvement in the canopy of the trees, the ' Leafless Twig ' condition becoming less conspicuous each year up to the end of 1958. In the beginning of 1959, however, there occurred a serious leaf fall, and the ' Leafless Twig ' condition appeared to be as bad as in 1955–56. The leaf fall was described previously as being at least partly due to *Phytophthora* infection of the leaves.

The most probable explanation for the loss of control in the 1958–59 season and the leaf fall in the beginning of 1959 is, that:

(*a*) Owing to the increase in number of leaves, the probability of infection of the leaves was increased;

(*b*) Owing to the increasing absolute number of Black Pods/tree (cf. *Table 5*)—it was shown above that the relative number of Black Pods was lower taking into consideration the larger mean number of pods/tree—the infection potential was higher. The mean number of Black Pods/tree was successively 8·3, 11·6 and 12·7 in 1955–56, 1956–57 and 1957–58 respectively;

(*c*) Owing to the denser leaf canopy the spray was not able to penetrate so well as in previous years to the site of young, disease-susceptible, leaf production;

(*d*) Owing to the shift of the beginning and the end of the spray season to an earlier part of the year, the period without spraying between 1957 and 1958 was shorter and may have prevented the leaf fall already taking place at the beginning of 1958 instead of the beginning of 1959.

If the empirically determined regression lines of *Figure 1* are transformed into the percentage ratio of Black Pods : total pods (*Figure 2*), it will be seen that the line passing through the origin ($y=0{\cdot}23\,x$) is a straight line.

The lines intercepting the negative part of the y axis show the relationship of increasing percentage of Black Pod with increasing number of pods/tree as found by Thorold. But the line intercepting the positive part of the y axis shows a decreasing percentage of Black Pod with increasing number of pods/tree.

The latter relationship was, as previously stated, considered to be related to a higher level of potential infection. For example, the 1958–59 graph shows that the level of infection was equivalent to 5 Black Pods. Hence each tree will lose at least 5 pods to Black Pod disease and a tree producing only 5 pods will suffer a 100 per cent loss.

The line $y=0{\cdot}23\,x$, which passes through the origin (*Figure 1*), represents the boundary in degree of infection in such a way that at higher levels of

infection the finding of Thorold no longer seems to hold owing to the fact that the infection level is exerting a larger influence than the number of pods/tree or, eventually, per population.

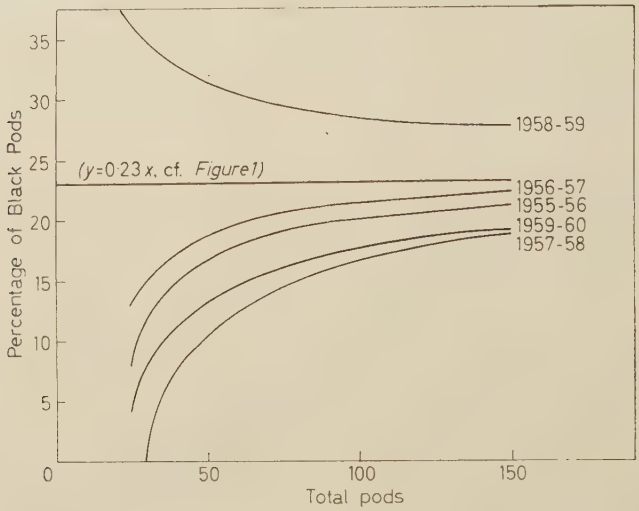

Figure 2. Percentage of Black Pods as a function of total pods

Below a certain level of infection (*Figure 2*), the maximum percentage of Black Pod incidence that can be obtained under the mitigating circumstances is approximately 23 per cent. This will be reached at a lower yield level (i.e. mean total number of pods/tree in a population) the higher the level of infection.

In the light of these relationships, it is of interest to find out which factors contributed to the potential level of infection. Previously three reasons were given for the sudden leaf fall in the beginning of 1959, i.e. the gradual build-up of the infection level is both the result of a larger absolute number of Black Pod infections and a larger number of leaves not covered by the spray. That these factors did not cause a leaf fall in the beginning of 1958 already, as might have been expected from the large level of potential infection in the 1958–59 season, is probably due to the fact that the last spray was applied late in 1957 and spraying was begun early in 1958.

The spray season ended much earlier at the end of 1958, so that for a period of five months no fungicide was applied. This together with the probability of a larger infection, particularly in places where owing to the denser canopy the spray did not reach, must have caused the fall of young leaves to occur in the beginning of 1959. The effect of it on the yield in the 1959–60 season is considerable, as may be seen from *Table 5*. The yield, which had been increased from 50 pods/tree since 1955 to 83 and 82 pods/tree in 1957 and 1958 respectively, dropped to 55 pods/tree, or by more than one third of its previous level.

Another consequence of it was that ' abnormal ' ratios between rejected and total pods were obtained for trees of varying production levels. It was suggested previously that two effects played a role in the potential

infection level: (*a*) the number of Black Pod infections and (*b*) *Phytophthora* infection of the leaves. With regard to the former, the starting point was a linear regression for Black Pods (y) to total pods (x). They are related to each other by the following formulae:

$$S(x-\bar{x})^2 = Sx^2 - nx^2;\quad S(y-\bar{y})^2 = Sy^2 - ny^2;\quad S(x-\bar{x})(y-\bar{y}) = Sxy - n\bar{x}\bar{y} \qquad \ldots.[1]$$

$$\left.\begin{array}{ll} b_{yx} = S(x-\bar{x})(y-\bar{y})/n : s_x^2 & \text{(regression coefficient)} \\ r_{yx} = S(x-\bar{x})(y-\bar{y})/n : s_x s_y & \text{(correlation coefficient)} \end{array}\right\} \qquad \ldots.[2]$$

Assume there are two populations of trees with exactly the same production, then it can be postulated that both their mean x ($\bar{x}$) and their sum of x (s_x), except for random deviations, are the same. If these two populations differ in Black Pod incidence, then the regression coefficients will differ only in the value of their numerator, and can be computed.

Adding to the lower Black Pod incidence a number of Black Pods y_i, then it is assumed that the higher Black Pod incidence is increased by a number 'a' and becomes z_i, hence $z_i = y_i + a$.

The numerator of the regression coefficient now becomes:

$$\begin{aligned} S(x-\bar{x})(z-z)/n &= Sxz/n - \bar{x}\bar{z} \\ &= Sx(y+a)/n - \bar{x}(\bar{y}+\bar{a}) \\ &= Sxy/n + Sxa/n - \bar{x}\bar{y} - \bar{x}\bar{a} \\ &= Sxy/n - \bar{x}\bar{y} + Sxa/n - \bar{x}\bar{a} \end{aligned} \qquad \ldots.[3]$$

Comparing this with the numerator of the regression coefficient b_{yx} (equation 2), it appears that the numerator is increased by the term $(Sxa - \bar{x}\bar{a})$.

Assuming that 'a', although varying from tree to tree, varies with standard deviation s_a around a mean $\bar{a}$, and further that 'a' is entirely independent of x, i.e. not correlated with total pods, then the term $Sxa - \bar{x}\bar{a}$ becomes nil. But then it has been assumed that, with increasing percentage Black Pod, the increase in number of Black Pods/tree for trees with for instance 10 pods is the same as for trees with 100 pods. This is unacceptable, the only acceptable supposition with regard to 'a' being that it is larger for trees with 100 pods/tree, in other words that 'a' is correlated, i.e. positively, with x. It implies that the term $Sxa - \bar{x}\bar{a}$ is positive, for this term is also the numerator in the formula for the correlation coefficient and indicates whether r (equation 2) will be positive or negative. The conclusion should therefore be: an increase in infection level resulting from an increase in Black Pod incidence at constant production levels is coupled with increasing values of the regression coefficients, hence the regression lines are not parallel. The fact, however, that the empirically determined regression lines were found to be parallel can then only be attributed to either of the following:

(*1*) There are real differences between the regression coefficients, but they are, owing to substantial random deviations, too small to become significant, or

(*2*) under certain conditions 'a' is not correlated with x.

The latter conditions could occur in the case of an increase in infection level resulting from an increase in *Phytophthora* leaf infection, when there are no pods on the trees, i.e. in the dry season. It was shown previously that the climatological conditions in Tombel are favourable for *Phytophthora*

infection throughout the year. This was, for instance, the reason why the leaf fall could occur in the dry season of 1959, when there were hardly any pods on the trees (cf. *Figure 3*: crop distribution 1958–59).

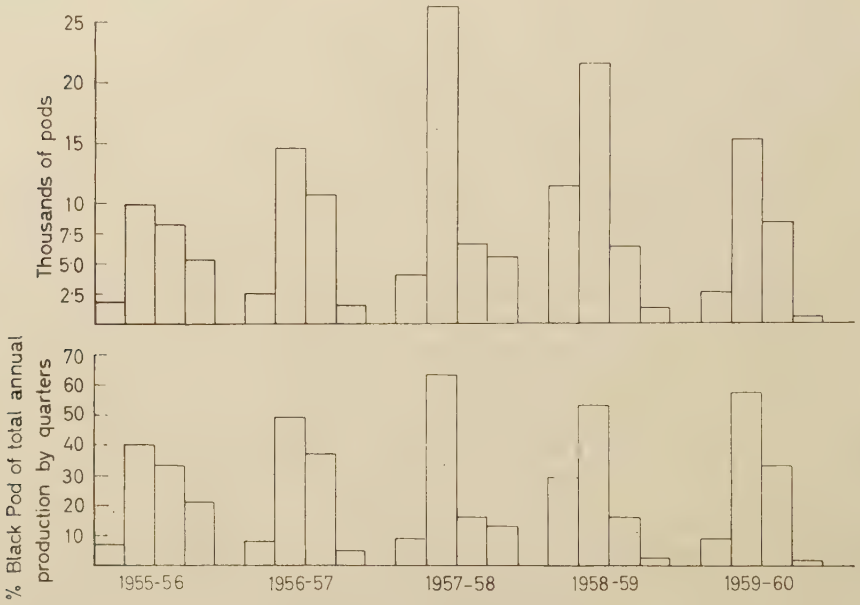

Figure 3. Crop and disease distribution

With regard to the first possibility above, i.e. the absence of real differences between the regression lines owing to substantial random deviations, it is of interest to note that the largest regression coefficient (0·26) was obtained in 1958–59, when the infection level was at its highest.

It might well be that the effect of the leaf infection on the total rate of infection was not such as to level off completely the effect of increased Black Pod incidence on the increase of the regression coefficient.

To summarize: there is a very obvious correlation between mean number of pods/tree and mean number of Black Pods (*Table 5*). If it is desired, say for testing spraying efficiency, to make comparisons as regards mean Black Pod incidence, it will be necessary to take into account the Thorold effect. Because of this effect, the infection level remaining equal, any increase in mean number of pods/tree should tend to result in a progressive increase in mean number of Black Pod infections. Consequently, neither the latter nor the ratio of Black Pods to pods/tree are quantities directly comparable, but require an adjustment for regression.

A further complication may, however, arise if the infection level is influenced independently of the yield level by *Phytophthora* leaf infection. Especially after a massive increase of *Phytophthora* of the leaves during a period when there are few pods on the trees, the relationship between number of Black Pods and number of total pods, as influenced by the latter, may become masked and the more so the higher that part of the total infection level that was induced by leaf infection.

There appear to be two ways of increasing the yield under Tombel conditions. First by decreasing the losses to Black Pod, and secondly by reducing the potential level of infection. Mistblowing the leaf canopy as well as the pods brought about a considerable increase in the yield level, i.e. of the order of 66 per cent, which resulted in an increase in the harvested yield of 40 per cent, or in terms of the harvested yield of 1955 56 of 71 per cent. Protecting the canopy is, therefore, as important as protecting the pods.

Finally, it is of interest to note the effect of spraying on the crop distribution over the successive years (cf. *Figure 3*). With increasing efficiency and earlier spraying, flowering and fruit set took place at the beginning of the season, and reached a maximum in 1958–59. Owing to the leaf fall in early 1959 the peak harvesting period came later than in 1958–59 but not so late as in 1955–56 or 1956–57 when spraying commenced later. These results confirmed the evidence collected by TOLLENAAR (1959) in respect of increased cocoa production as an additional effect of foliar copper applications, but they did not support his interpretation of it being a nutritional rather than a fungicidal effect of copper.

SUMMARY AND CONCLUSIONS

Once the relationship between yield and Black Pod is known in an area for one year it becomes possible to predict the potential loss for any other yield. By comparing the potential loss with the actual loss an assessment of efficiency of the control methods may be made.

At Tombel all the results are based upon disease incidence in cacao where considerable efforts were made to control the disease. If no control methods were applied the loss would have probably been of the order of 60 to 80 per cent. THOROLD (1956) observed that at Kumba, not far from Tombel, 68 per cent of the pods produced by trees yielding 60 or more pods were infected. The only control method was a fortnightly Black Pod removal cycle. This information cannot be applied directly to the yields at Tombel but it may be concluded with safety that had no spraying taken place at Tombel the losses through Black Pod disease would have been in excess of 60 per cent. That the loss was reduced to an average value of about 15 per cent demonstrates the efficiency of mistblowing as a disease control method. But it appears that even this method is inadequate once the leaf canopy is dense and it is thought that spraying should be carried out also when there are no pods on the trees, i.e. in the dry season, in order to protect the young leaves. It is not yet established how frequent this dry season spraying should be. At Tombel the trees are planted on a four metre square and the trees at 30 years of age are of such a size that canopy spraying is a difficult task and probably it would have to be done by aircraft. In future planting, consideration should be given to this problem and one answer might be to plant a quincunx and after a certain period of years remove the centre tree.

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Preliminary Trials of West Indian Xanthosoma *Cultivars*

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The tannia is indigenous throughout the West Indies and is commonly grown by small farmers for its edible tubers, but its popularity is not as great as that of sweet potatoes, yams, or dasheen and eddoes. Gooding (1958) has estimated that there are at least 15 cultivars existing in the eastern Caribbean and most of these have been collected from the various islands for description and trial in Trinidad.

The genus *Xanthosoma* consists of several tuber-bearing species which have been variously classified as *X. sagittifolium*, *X. atrovirens*, *X. violaceum* and *X. caracu*. Because of the confusion which exists with these polymorphic species, it is difficult to give specific names to these cultivars. However, from the descriptions given by Haudricourt (1941), who has quoted at length from Engler's (1919) key to the cultivated species of *Xanthosoma*, it would appear that most of those described in this paper belong to the species *X. caracu*. The cultivar 22/57, obtained from Barbados, is probably identical with the 'Rolliza' cultivar described by Barrett (1905) and later identified by Engler (1919) as belonging to this species. On the other hand the cultivars 'Molkon' 11/56 and 'Nut Eddoes' 12/57, briefly described by Whitehead (1958) may belong to a different species.

Very little information is present in the literature on the yields and storage capacity of this potentially important crop. Barrett (1905) quotes yields of 10 to 15 tons of tubers per acre obtained in Puerto Rico and in a later article (1910) states that small amounts of tubers can be kept for six months in a dry atmosphere. Other descriptions of cultivars have been given (Paine, 1939; Quisumbing, 1914 a, b and Abadilla, 1917), but even where the work proceeded beyond the stage of morphological description the information on yields and storage is very scanty.

The seven clones, used in the trials described, are selections made from the preliminary observation plots of the original accessions. The reasons for including them are as follows: 22/57 because of its high yield, good tuber shape and relative absence of suckering; 13/56, 14/56, 12/56 and 09/56 because of yield and tuber shape; 12/57 because of its reported good storage qualities in Barbados even though it produces small tubers, and finally 11/56 because of its early maturity. The last named clone has pink flesh while the others are white fleshed. All these selections have a chromosome number of 26, except perhaps that of 12/56 which has not yet been counted.

Table 1. Mean yield of tubers expressed in tons per acre
Planted 28/4/58 Harvested 6/2/59
Plot size: Sub-plots of 16 plants planted 3 ft × 3 ft, net sub-plot size 4 yd² with 4 plants

Accession number	*Vernacular name*	*Origin*	*Marketable tubers*			*Marketable and unmarketable tubers (Total yield)*			
			Rhizome plots †	*Tuber plots* ‡	*Mean* ± 0·91	*Rhizome plots* †	*Tuber plots* ‡	*Mean* ± 1·09
22/57	?	*Barbados*	13·8	10·9	12·3	16·6	12·2	14·4
12/56	*Charanelle*	*Trinidad*	13·4	9·6	11·5	15·9	11·4	13·7
14/56	*Choubouton*	*Trinidad*	12·8	9·1	11·0	18·2	12·6	15·4
13/56	*Chackelle*	*Trinidad*	10·1	9·0	9·0	11·8	10·7	11·2
09/56	*Dearies*	*Trinidad*	8·4	6·5	7·5	10·3	7·9	9·1
11/56	*Molkon*	*Trinidad*	4·4	4·0	4·2	7·1	6·5	6·8
12/57	*Nut Eddoes*	*Barbados*	3·2	4·1	3·6	7·0	10·9	9·0
		Mean ± 0·37	9·5	7·6	8·5	*Mean* ± 0·40 12·4	10·3	11·4

† Horizontal comparisons ± 0·98
‡ Other comparisons ± 1·14

Standard errors:
Whole plots ± 1·82 tons per acre or 21·4 per cent (18 d.f.)
Sub-plots ± 1·96 tons per acre or 23·0 per cent (21 d.f.)

† Horizontal comparisons ± 1·07
‡ Other comparisons ± 1·32

Standard errors:
Whole plots ± 2·17 tons per acre or 19·1 per cent (18 d.f.)
Sub-plots ± 2·14 tons per acre or 18·8 per cent (21 d.f.)

This paper attempts to extend the information available on the yield and storage capacity of the tannia and to report as well on preliminary results obtained on the depth and spread of the tubers and their mechanical harvesting. The experiments on storage and the organoleptic tests were carried out by OYEBOG (1959), a postgraduate student at the Imperial College of Tropical Agriculture, in part requirement for the Associateship of the College.

YIELDS

In the yield trial the seven clones were compared in four randomized blocks, the plots being split to test two kinds of planting material (portions of the main rhizome or heads, and tubers). This comparison of planting material was considered desirable to confirm that a higher yield is obtained by using the main rhizome, as reported by BARRETT (1905) and others. The yields obtained in this trial are summarized in *Table 1*. The mean yield of marketable tubers from the rhizome plots was significantly higher than from the tuber plots, 1·9/0·52 (S.E. of diff.)=3·65, that is, significant at the 1 per cent level (t=21 d.f.).

Table 2. Suckering of tannia clones (8 plants per plot)

Accession number	*Percentage suckering*	*Percentage of suckers (transformed to degrees)*
		S.E. ±2·865
11/56	46·78	43·01
09/56	37·36	37·63
14/56	35·22	36·33
12/57	30·28	33·16
13/56	17·09	23·89
12/56	13·34	21·23
22/57	10·14	17·73

Taking individual clones, however, only 22/57, 12/56 and 14/56 were significantly superior at the 5 per cent level. In the other clones yields of marketable tubers from the rhizome and tuber plots were very similar. This was probably due to the occurrence of suckering, that is the percentage of grown-out tubers was high (*Table 2*). This indicates that the planting material also was probably obtained from small heads, or rhizome pieces, due to the nature of the plant and this gave them only a slight advantage or even a disadvantage as compared to plants grown from tubers. In apparently early clones like ' Molkon ', and even in ' Nut Eddoes ', tubers sprout readily in the soil and it is difficult to decide on the best harvesting time as these suckers soon give rise to further tubers.

The only tannia pest, occasionally serious in the field, is *Ligyrus ebenus* which is a Dynastid beetle. This beetle has been described by CLEARE (1930) from observations made in British Guiana. The tubers in the yield trial attacked by this pest were counted and the percentages of damaged tubers of each cultivar are given [*Table 4*(b)]. As these percentages showed little variation between cultivars and were generally low, about 2 to 3 per cent, the data were not analysed.

MECHANICAL HARVESTING OF THE CROP

In the West Indies tannias are often grown on virgin soils in wetter hilly districts in small pure stands or as shade for the establishment of cocoa. Very little systematic planting is done and the crop, when grown, is generally of more importance to the farmer's own home consumption rather than for sale. Harvesting is often performed by removing the soil around the base of the plant, excising the mature tubers, replacing the soil and leaving the parent plant to continue growing. Further harvests are made in a similar manner and the tubers are therefore available over a long period.

Judging by the high yields of marketable tubers obtained in the current yield trial and the high prices of tubers on the local market, the economics of large scale cultivation appear very reasonable and further investigation on this point is necessary. To obtain some preliminary information, about 0·2 acre of flat land was planted with clones 22/57 and 13/56, at a spacing of 4 ft between the rows and 3 ft within rows. The land was ploughed and ridged mechanically. Farmyard manure was applied by hand and the pieces of rhizome also covered manually. Two hand weedings were carried out and at the same time the soil was hoed up to maintain the ridges. Growth was very good indeed, despite unusually dry weather after planting, and yields fairly high (12 760 lb/acre).

Information on the depth and spread of the tubers in relation to the ridges was obtained by carefully removing the soil around ten sample plants of each cultivar to expose the tubers (*Figure 1*). The measurements were recorded (*Table 3*). For both cultivars, the spread along the ridge was greater than that across the ridge and the maximum depth of tubers from the top of the ridge rarely exceeded 11 in.

Table 3. The depth and spread of tannia tubers at harvest time
Planted 14/4/59 Harvested 22/1/60

Accession number	*No. of plants in sample*	*Maximum depth of tubers in.*	*Standard deviation*
22/57	10	9·02	±0·72
13/56	10	9·12	±0·95

Accession number	*Maximum spread of tubers across ridges in.*	*Standard deviation*	*Maximum spread of tubers along ridges in.*	*Standard deviation*
22/57	19·25	±1·85	19·60	±2·71
13/56	17·05	±1·13	20·90	±3·01

A mechanical harvester, currently being developed at the Imperial College of Tropical Agriculture for 'White Lisbon' yam (*Dioscorea alata*) harvesting was used on these tannias. It is 22 in. wide and will go 11 in. in depth and thus from the data obtained (*Table 3*) it would appear that damage to tubers when using this harvester would be relatively slight. Prior to harvest it was necessary to cut the tops off by hand to just above the soil level and remove them from the field.

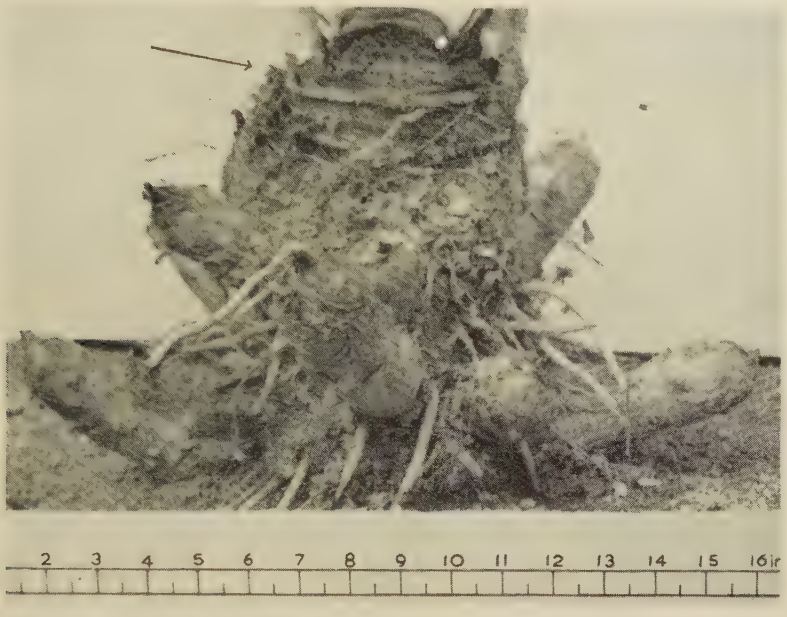

Figure 1. A plant of 22/57 with the soil removed to show the tubers. The arrow indicates soil level (scale in inches)

Two trial runs were made with the harvester at different speeds; at a slow rate 394 lb of tubers was harvested of which 8·9 per cent by weight was damaged; at a faster rate 1 701 lb of tubers was harvested with 6·3 per cent by weight damaged. Altogether 2 095 lb of tubers was harvested mechanically and 142 lb or 6·8 per cent mechanically damaged. As a comparison, 177 lb was harvested by normal hand methods and the damage was 2·3 per cent.

This trial serves to indicate that mechanical harvesting of tannias on flat land is possible; but both the harvester itself and the techniques of cultivation of the crop will need further modification and study.

STORAGE AND TASTING TESTS

To investigate the storage qualities of the seven clones used in the yield trial, four ten-pound samples of pest- and disease-free tubers were selected from each clone. The tubers were laid out on raised wire racks in the farm food crop store where a daily average temperature of 79°F and humidity of 76 per cent prevailed. A further ten-pound sample from each of the cultivars was stored at 45°F with a relative humidity of about 80 per cent.

After four to six weeks storage the tubers in the replicated trial were found to be attacked by *Araecerus fasciculatus*, an Anthribid beetle which causes serious holing of the tannias. The adult flies from one tuber to another depositing eggs and the larvae burrow inside the tubers reducing the flesh to a firm dry mass. Susceptibility to attack varied considerably [*Table 4* (a)]. All the clones were significantly less attacked than 12/57 ' Nut Eddoes '. On the other hand 09/56 ' Dearies ' was significantly better than 11/56 and 14/56 at the 1 per cent level. There was little sign of disease.

Sprouting started during the sixth week of farm storage (*Table 5*). It was noted that the apical buds of the tubers tended to sprout first. Under the high temperatures of storage, these buds often dried off, whereupon lateral buds started to sprout and these in turn dried off. This resulted in considerable fluctuations in the numbers recorded as sprouting. On the first count (*Table 5*) 12/57 ' Nut Eddoes ' was clearly the worst in this respect.

Table 4. Susceptibility of tannia tubers to insect attack

Accession number	(a) Araecerus fasciculatus (*per cent tubers attacked during storage*) *Means*		(*b*) Ligyrus ebenus (*per cent tubers attacked in field*)
	Transformed to degrees	*Nearest whole per cent*	
12/57	55·47	68	2·6
11/56	22·81	15	1·5
14/56	19·69	11	3·0
12/56	17·22	9	3·3
22/57	15·38	7	3·3
13/56	4·48	<1	2·8
09/56	3·54	<1	2·6

S.E. ±3·73

Table 5. Sprouting of tannia tubers during the sixth week of storage

Accession number	*Sprouting percentage*	*Accession number*	*Sprouting percentage*
12/57	67	*09/56*	14
22/57	38	*11/56*	8
14/56	34	*13/56*	6
12/56	32		

The percentage germination was recorded weekly from six to twenty-one weeks and a graph of the records showed that 12/57 and 14/56 sprouted the most over the period and 09/56 the least, while the remainder gave intermediate results. A statistical analysis was carried out on these records and this indicated that all the clones were significantly lower sprouting than ' Nut Eddoes ' (12/57) and ' Choubouton ' (14/56) at the 0·1 per cent level. None of the tubers in the ' cold ' store had sprouted during the same period.

Fortnightly records were also taken of percentage loss in weight. During the first fortnight losses ranged from 7 to 11 per cent; this rate dropped to 0·75 to 3·0 per cent for the second fortnight; and for the subsequent five fortnights, weight losses varied between 0·3 and 3·3 per cent. The results over the whole period are given in *Table 6*. 09/56 ' Dearies ' lost significantly less weight than all other clones at the 0·1 per cent level, whilst the remainder were significantly better than ' Nut Eddoes ' at this same level of significance.

In ' cold ' storage the weights of all clones remained constant up to the ninth week, but between the tenth and twelfth weeks they all dropped four ounces in weight (2·5 per cent).

These preliminary experiments demonstrate how 'cold' storage can considerably assist in lengthening the availability of tannias for the market and that certain clones can be kept, even under normal conditions, for at least two months without excessive loss in weight. This loss nevertheless indicates that a quick sale is desirable unless a grower can command an enhanced price by keeping the tubers longer. Further investigations are required on storage buildings of an improved design in order to lower this initial high loss.

Table 6. Weight losses of tannia clones in farm storage

Accession number	*Name*	*Mean loss in weight (oz) over fourteen weeks*	*Percentage loss in weight*
12/57	*Nut Eddoes*	128·89	20·14
11/56	*Molkon*	100·11	15·64
14/56	*Choubouton*	88·55	13·84
13/56	*Chackelle*	81·62	12·75
12/56	*Charanelle*	79·85	12·48
22/57	*Barbados*	75·29	11·76
09/56	*Dearies*	49·19	7·68

S.E. of means $= \pm 4{\cdot}71$

Insects, by eating the skin, appear to cause an increase in water loss from the tubers. This is probably one of the causes of the large loss in weight from 12/56, which was included in the trials originally because of local reports of its good storage qualities. The loss of water from the broken ends of the tubers where they are detached from the parent rhizome is also probably an important factor and tubers with narrow 'necks' are thus desirable. This character varied with the different clones.

Table 7. Numbers of weeks during which the optimum eating quality was maintained

Accession number	*Farm store*	*'Cold' store*
12/56	9	19
13/56	18	19
22/57	10	19
14/56	9	19
11/56	9	18·5
09/56	9	18·5
12/57	10	20·5

For the organoleptic tests, carried out fortnightly, a balanced incomplete block design was used, with clones being grouped in sets of three. These groups were randomized among the tasters so that each clone was tasted three times at each test. The cooking was carried out under uniform conditions using a pressure cooker at 15 lb/in^2 for ten minutes. Prepared forms were issued to the tasters to fill in while tasting. Marks were awarded on the basis of an arbitrary scoring scale, which had been pre-determined. Preliminary tests showed that none of the clones caused any itchiness in the throat nor were very hard and there was no particular preference for flesh colour.

Subsequent tests showed that the clones could be divided into three classes, (*a*) high quality: 12/56 and 13/56, (*b*) medium quality: 22/57, 14/56 and 11/56, and (*c*) low quality: 12/57 and 09/56. Tubers possessing a very good taste were soft and not sticky or fibrous. For farm storage, optimum eating quality was maintained in all clones up to nine weeks and for ' cold ' storage up to eighteen weeks. Rate of decline of eating quality varied from clone to clone. The number of weeks during which the optimum eating quality was maintained for each clone is given in *Table 7*.

SUMMARY

The yields and certain related factors, storage, mechanization and eating qualities of seven *Xanthosoma* clones are described. Considerable variation is shown to exist between the clones except for the two with the best overall qualities, namely 22/57 and 12/56 which are probably identical. Yields of over 13 tons of marketable tubers per acre were obtained from these two clones and the weight loss over fourteen weeks of storage under normal local temperatures and humidities did not exceed 13 per cent. Optimum eating quality was maintained for nine weeks under these conditions and for more than eighteen weeks when stored at 45°F and about 80 per cent relative humidity. Mechanical harvesting appears possible on flat lands.

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Protein for Egg Production in Ghana

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Under the stimulus of an acute shortage of animal protein in the West African diet, egg production is becoming increasingly important (Lansbury, 1960). At present the rapidly increasing numbers of large scale poultry farmers are dependent upon imported balanced rations which are extremely expensive. Continued dependence on imported feeds is rather undesirable but the compounding of locally grown poultry feeds is limited by the acute shortage of animal protein. In the U.S.A. it has been found practical to use all-vegetable diets fortified by riboflavin and vitamin B 12 additives, using soya bean meal which has a good balance of amino acids, as the main protein source. A shortage of animal protein feeds stimulated similar research in the U.K. where imported groundnut cake was available in large quantities. Carpenter, Duckworth and Ellinger (1951a, 1951b, 1954) conducted trials comparing groundnut cake meal and soya cake meal as protein sources with and without animal protein additives. A general conclusion from their first report was that growth and feed conversion efficiency up to point of lay were as good in groups fed on all-vegetable rations containing 18 per cent of crude protein mostly from groundnut cake in the starting ration, and 16 per cent in the growing ration, as in groups fed on regulation rations of the same protein content. There was a transitory check in early growth which could be avoided by adding animal protein supplements but this did not improve growth and efficiency over the whole rearing period. The addition of riboflavin to these starting rations was essential. In the second series of tests, the first experiments were continued through a full laying season. Birds fed on rations devoid of animal by-products from hatching until 18 months of age were equal in laying performance and health to those that had received animal supplements.

The significance of these experiments is very great in terms of the West African agricultural economy since very large quantities of groundnut cake are available in Nigeria and it is likely that with the present expansion of groundnut farming in Ghana there will be increased supplies available in the near future. Soya beans have never been a popular crop with government extension officers due to rather disappointing yields and the almost insurmountable problem of persuading people to eat them, together with other technological problems involved in the preparation of soya bean feeds. These difficulties have been reviewed and suggestions made for the use of soya bean as human food by Professor Platt (1956), but it is as soya bean meal, a by-product of soya oil production, that soya bean can offer a valuable protein source for poultry in West Africa. Consistently high yields on the field scale have been obtained from the better varieties of soya bean at Nungua, the University College Research Station on the Accra

Table 1. Amino acid composition of experimental diets, based on HARVEY, *1956*

Feed	*Arginine*	*Glycine*	*Histidine*	*Leucine*	iso*Leucine*	*Lysine*	*Methionine*	*Phenyl-alanine*	*Threonine*	*Trypto-phane*	*Valine*	*Total cystine methionine*	*Total ph.-alanine & tyrosine*
Diet A													
10 % Groundnut cake	0·44	0·25	0·125	0·29	0·20	0·14	0·04	0·20	0·115	0·06	0·25	0·08	0·34
10 % White fish meal	0·36	0·36	0·18	0·64	0·48	0·59	0·18	0·29	0·38	0·05	0·42	0·26	0·49
10 % Palm kernel cake	0·27	0·09	0·04	0·13	0·07	0·07	0·03	0·08	0·06	0·02	0·09	0·06	0·13
70 % Maize	0·37	0·20	0·15	0·77	0·25	0·18	0·13	0·30	0·32	0·07	0·48	0·26	0·57
Total	1·44	0·90	0·50	1·83	1·00	0·98	0·38	0·87	0·88	0·20	1·24	0·66	1·53
Diet B													
30 % Groundnut cake	1·32	0·75	0·38	0·88	0·61	0·42	0·11	0·61	0·34	0·19	0·75	0·26	
10 % Palm kernel cake	0·27	0·09	0·04	0·13	0·07	0·07	0·03	0·08	0·06	0·02	0·09	0·06	
60 % Maize	0·32	0·17	0·13	0·65	0·22	0·15	0·11	0·26	0·28	0·06	0·41	0·22	
Total	1·91	1·01	0·55	1·66	0·90	0·64	0·25	0·95	0·68	0·27	1·25	0·54	1·65
Diet C													
15 % Groundnut cake	0·66	0·36	0·18	0·43	0·30	0·21	0·05	0·30	0·17	0·09	0·37	0·11	
10 % Palm kernel cake	0·27	0·09	0·04	0·13	0·07	0·07	0·03	0·08	0·06	0·02	0·09	0·06	
15 % Soya bean cake	0·42	1·14	0·18	0·60	0·42	0·48	0·06	0·33	0·33	0·09	0·39	0·16	
60 % Maize	0·32	0·17	0·13	0·65	0·22	0·15	0·11	0·26	0·28	0·06	0·41	0·22	
Total	1·67	1·86	0·53	1·81	1·01	0·91	0·25	0·97	0·84	0·26	1·26	0·55	1·61
Recommended level	1·2	1·0	0·3	1·4	0·6	0·9	0·9	1·6	0·6	0·25	0·8	0·9	1·6
Percentage of recommended (N.R.C., 1954) A	134	106	193	142	188	120	42·2	54·4	155	80	175	73	90
Percentage of recommended (N.R.C., 1954) B	161	103	183	122	152	71	27·8	54·4	117	108	161	60	106
Percentage of recommended (N.R.C., 1954) C	146	186	180	126	162	101	27·8	60·7	132	104	157	60	101

plains (HILL, 1960), and provided an outlet can be found for the excellent quality cooking oil produced it is a crop which deserves encouragement.

The American and British work described so far has all been carried out under very different conditions from those found in West Africa; furthermore the basic cereal foods used are different in the case of the British investigations. It was therefore decided to carry out at Nungua a series of feeding trials based on the work of Carpenter *et al.*, using all-vegetable rations of local origin.

EXPERIMENT I

450 day-old Brown Leghorn × Light Sussex pullets were purchased from a commercial hatchery in Kent, and were sent by air to Accra. This particular cross and source of chicks was chosen as it had performed well in previous growing and laying trials at the Nungua research station.

A serious delay of three days in transit resulted in the chicks arriving in a rather weak and distressed condition due to lack of water and food together with extreme heat stress. It was considered unwise to handle the chicks any more than absolutely necessary and after a good feed of an orthodox chick starter meal they were distributed at random, without individual weighing, among a total of 9 groups made up of 3 treatments × 3 replicates.

The chicks were kept in small houses with wire runs raised off the ground. The solid floors of the houses were covered with wood shavings which were changed frequently. Water and food were supplied in orthodox fountains and troughs. Records of food consumption were kept but were of only approximate value since it was not possible to collect spilled meal quantitatively.

Table 1 shows the constituents of the diets and the amino acid make up. The treatments were designed to provide a comparison between an orthodox, animal protein-supplemented diet which was nutritionally complete for amino acids, and two vegetable diets (B & C) both of which were by theoretical standards (N.R.C., 1954) seriously deficient in total cystine and methionine and one of which (B) was also deficient in lysine.

All treatments received commercial vitamin and mineral supplements.

Each group of chicks was weighed weekly and the mean of the three replicates recorded and expressed as a percentage of the mean of the animal protein-supplemented treatment replicates.

At four weeks, doors in the wire runs were opened to allow the chicks out into an extended wire run at ground level. Herbage and insect life were very sparse and it is assumed that there would not be sufficient to contribute to the growth behaviour of the chicks.

RESULTS AND DISCUSSION

The weekly mean weights of the three groups of chicks in each treatment are presented graphically in *Figure 1*. At the end of the first week surprising differences occurred between treatments. This was not a direct effect of the treatments but was due to the rather slow start at eating made by the chicks on all-vegetable diets presumably due to their finding the all-vegetable diet unpalatable after the single feed of orthodox chick starter meal they received as a life saver on first arrival. The differences between

treatments became progressively greater up to the sixth week by which time the birds on the lysine and cystine–methionine deficient diet (B) reached the very low value of 60 per cent of the weight of the animal protein group (A). The cystine–methionine deficient group (C) had fared somewhat better but were still at the very low level of 68 per cent of the A group. Feathering was far more advanced in the A group than the B group with C intermediate. There was a slight tendency to feather picking among one house of B chicks but this ceased when the runs were extended down to ground level thus reducing overcrowding and enabling the birds to amuse themselves scratching.

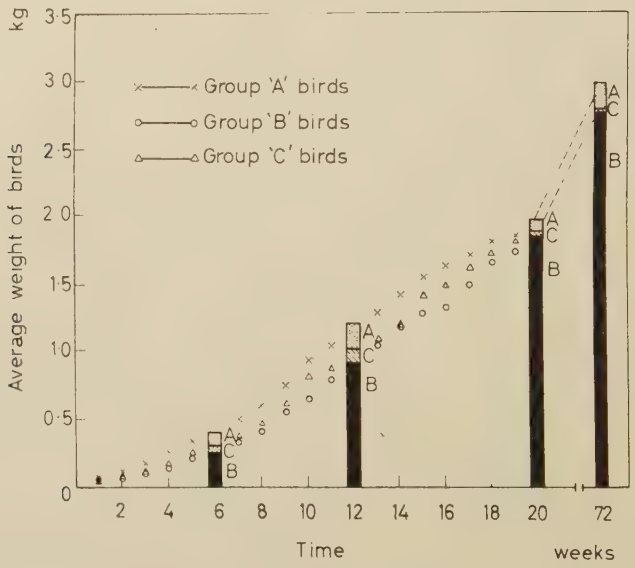

Figure 1. Poultry feeding experiment

As in the experiments reported by CARPENTER *et al.* (1951 a, b), this difference was transitory and by 12 weeks the differences had closed to 100, 73 and 80 for A, B and C diets respectively and at 21 weeks the differences had closed to 100, 92 and 96.

It is clear from an inspection of the amino acid composition of diet B in *Table 1* that total cystine–methionine and lysine are seriously deficient. The recommended levels for these acids are known to be high (CARPENTER *et al.*, 1951 a, b) but the levels in the diets used are clearly too low to be within reasonable safety margins. The effect of this deficiency has been to reduce seriously the rate of growth during the period of very rapid growth from 0 to 6 weeks when the demand for the essential amino acids lysine and cystine–methionine is likely to be at its greatest.

As the rate of growth slows down it is clear that the chick is able to obtain sufficient of these amino acids for normal growth to be resumed and for some of the lost growth to be made up. In this experiment the pullets did not make a complete recovery by 21 weeks.

When formulating diet C the lysine was increased, without greatly altering the proportions of other amino acids, by the inclusion of soya meal. Although still below the recommended level, it is likely, since National Research Council recommendations have considerable safety margins, that the lysine level approached the true requirement. The difference between B and C at any rate indicates a considerable response to the addition of lysine-rich soya meal.

The continued low growth rate of the C group relative to A leaves no doubt that cystine–methionine is also an important limiting factor.

From the somewhat limited information provided by this experiment it is clear that the apparent amino acid deficiencies in local all-vegetable diets together with reduced intake due to unpalatability, may have a real effect on growth rates of very young poultry. The fact that these effects are at any rate partially transitory may make them unimportant in birds intended for egg production provided there is no permanent damage to the genital system, i.e. egg-laying potential. The present experiment was extended to examine this aspect.

For flesh production whether as 16 week roasters, or even more important, as broilers, rapid growth in the early stages is essential. A serious setback in the first six weeks could not be tolerated, however transitory. This leaves us with the choice of retaining expensive imported white fish meal as a constituent of Ghanaian poultry rations or finding alternative sources of lysine and cystine–methionine within the country. Soya and carefully dried cow dung are good sources of lysine. Cystine–methionine is less easy to find but two promising crops are sesame (beniseed) and sunflower. The oil of both these crops is of good quality and the residual cake could be of great value in poultry nutrition. However, as with vitamins B 2 and B 12, which were formerly supplied by animal by-products, new and cheaper techniques of production are rapidly bringing the cost of synthetic methionine down to a level where the addition of the very small quantities required to supplement Ghanaian all-vegetable rations could be practicable. The cost of synthetic lysine, which at present is prohibitive, may also fall as new techniques of production are evolved.

EXPERIMENT IA

The birds from experiment I were transferred to the battery at 22 weeks of age. The birds on diet B began laying about a week later than the other two groups. Egg production data over a laying season are presented in *Figure 2*.

It can be seen that there is no difference between the groups although the body weight of the B group had fallen back to 90 per cent of the control group A by 18 months (see *Figure 1*).

CONCLUSION

Chicks can be successfully reared from day old to the end of a laying season on two all-vegetable rations made up of locally grown cereals and local oil cake by-products. Deficiencies of lysine in one ration and deficiencies of cystine–methionine in both rations caused a transitory check which had no effect on overall egg production and food utilization. This

check would be undesirable in table birds and can be partially alleviated by the use of soya bean meal which is rich in lysine. Synthetic methionine may be useful in further reducing this check.

Although birds on the B diet produced as many eggs as A or C diet birds it is likely that at about six weeks they are suffering from malnutrition which could cause a susceptibility to infection or vices such as cannibalism. As the birds on B and C diets caught up with the A group between eight weeks and point of lay it is evident that these diets are adequate for growers and layers.

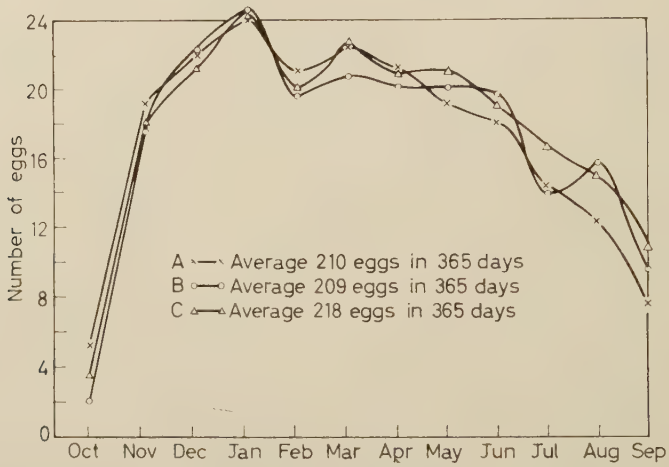

Figure 2. Egg production

A provisional recommendation could be restriction of the use of white fish meal or imported concentrated protein balancers to diets for chicks up to eight weeks of age and breeding stock. Since the amount of food eaten by these classes of birds is small, the economy effected would be great.

As more and more by-products of soya, sunflower and beniseed oil become available it will probably become possible to do without even this small amount of white fish meal and thus become even more self-sufficient. It is to this end that a further and more comprehensive set of experiments on all-vegetable diets has now been initiated at the Nungua Research Station of the University College of Ghana.

ACKNOWLEDGEMENTS

The author wishes to make acknowledgements to Mr A. S. B. Wilson who has provided many ideas and much of the background information for this article; to Mr M. G. C. McD. Dow, and Mr G. L. Mabey for help with the table and figures, and lastly to the assistants who have carried out the field experimentation, Mr G. Tetteh Adams and Mr M. A. Addo.

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Productivity of Pasture in British Honduras—III

Jaragua Grass

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A beef cattle industry is one of the possibilities always referred to for the development of British Honduras. Wright *et al.* (1959) state that 730 000 acres in British Honduras are suitable for permanent pasture, plus 970 000 acres suitable for leys. A census under the general direction of one of the authors (D. H. R.) has shown that in May 1959 there were 23 000 acres of pasture in the territory, together with 10 000 acres of rough grazing: in addition, cattle roam over about a quarter of a million acres of natural savanna of very low productivity—the Tok and Puletan soils described by Wright *et al.*

In the past, cattle rearing has been done only on a most haphazard basis by people with no knowledge of commercial cattle husbandry or how to fatten animals for a specific market. Only in recent years has this been attempted, and with sufficient success to warrant future expansion. Naturally, this has led to increased attention being paid to nutrition and therefore to various species of higher yielding pasture grasses. Romney (1960) has shown the poor dry-season productivity of natural pasture in British Honduras. From the many grasses tried, only a few have emerged as being of real value. Of these few, Jaragua grass (*Hyparrhenia rufa*) appears to be of sufficient promise to be advocated as a general purpose, economically established, range/fattening and drought-resistant grass which will adapt itself to many areas of the country.

DISTRIBUTION

Jaragua grass grows over wide areas of Central and South America, and is used extensively for cattle feed. It is said to occur naturally in the Pacific lowlands of Costa Rica (Report of the National Centre of Agriculture, Costa Rica, 1938), although Aguilar (1939) gives Africa as its origin. It is also used in Costa Rica for improved pastures (Becker, 1943). In Brazil, it is planted in many areas, even in the arid State of Ceara (Dominguez, 1941). In the State of Minas Gerais it is used for ensilage (Alves and Silva, 1936) and for hay (Mendes, 1944). In the Llanos of Colombia and in the Bolivian savannas, where there is absolute drought for three to five months, it is planted for its drought-resistance and for the success with which it competes with and smothers weeds (Rueda and Reyes, 1941). The grass also grows in the Republics of Honduras and Guatemala, and in British Guiana.

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Jaragua grass was first introduced to British Honduras from the Republic of Honduras about thirty years ago. Seed was sent to the property of Chiall in Cayo District, where it was sown and managed in a haphazard manner, with the result that it was not considered to be of value for grazing purposes. It stayed confined to this property until 1951, when one of the authors (E. D. S. K.) at Calla Creek started to plant and use it as an improved pasture grass. From this small beginning, it has interested many small farmers in this district with the result that there has been a considerable acreage established.

Due to the efforts of the Department of Agriculture in promoting pasture improvement, it has rapidly become the pasture grass of choice in many localities. It has been introduced into Orange Walk district under the Pasture Subsidy Scheme and appears to grow fairly well, although not with the same vigour as seen in Cayo. This may be due to a different strain of grass from Guatemala being used. It has also been successfully grown by Chopin* in both Toledo and Stann Creek.

The grass has also spread noticeably and established itself over the past ten years along the verges of the principal highways of the country, probably due to seed dispersal during transportation, and has been observed growing in the infertile coastal pine ridge of Belize district as well as on the Mountain Pine Ridge.

It would appear, therefore, that it will grow on the varied soils and under the diverse climatic conditions of most of British Honduras. As yet it has not been observed growing in Corozal District, probably due to the fact that as yet no seed has been introduced there. However, on soils which are badly drained its place is soon taken by *Paspalum virgatum* L., known locally as sour grass.

DESCRIPTION

Hyparrhenia rufa (*Andropogon rufus* Kunth) is a tall erect grass growing in tufts, the culm at flowering being 6 to 8 ft high as observed in Cayo District and Toledo, but only about 4 to 5 ft high in Orange Walk and Stann Creek. The cylindrical culm commences growth in October–November and emerges from a tuft of about 24 in. in height, consisting of narrow leaves which are up to 1 in. broad and may be as long as 20 in. During growth of the culm the internodes, which are about 3 to 5 in. in length, are whitish in colour. The sheaths of the leaves enclose about half of the length of each internode, giving the culm a banded appearance. The ligules are thinly membranous, brown in colour and surrounded by short fine hairs.

The flower which appears in December to November is a loose panicle, each stalk bearing approximately 50 seeds, which when ripe turn a dark brown colour and are flattened and about 1/8 in. long. Each seed has a long flexuous awn. The culm remains erect under natural conditions after seeding in December. If the grass is cut at this stage, a second culm will appear and bear seed, but will not be so tall as the first and seed viability appears to be much less. Continued cutting will result in persistent culm growth and seed production until the rains in June, after which there is little seed produced until December.

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SEED COLLECTION AND STORAGE

Depending on the weather, collection is usually undertaken any time during the month of December when the seed at the bottom of the panicle is beginning to fall, and has turned dark brown in colour. Harvesting is done by hand. The stalks bearing the seeds are cut off in lengths of about 2 ft, which is generally thought to be a convenient length for handling.

If the harvesting month is dry, the seed is dried in the field, the culms being placed in layers similar to thatch, i.e. each succeeding layer is lapped over the one below so that the seed heads of the layer underneath are exposed to the sun. The piles of culms should not exceed 3 ft in height, in order to avoid overheating. After three to four days of sunning the culms are turned and shaken to dislodge the seed. This operation is preferably carried out in the early part of the day, so that the seed can be spread out and dried before bagging in the evening. The seed which is still attached to the stalks is left to dry for a further two days and then shaken off.

If the weather is wet during harvesting, the stalks are cut as usual and then dried under cover. The recommended method is to construct tiers of drying racks made of 2 in. mesh wire netting, and to arrange the stalks thereon in layers. By this method, the seed can be dried out and collected in 4 to 5 days, with a minimum of labour and negligible seed damage through overheating.

Final sun-drying prior to storage is always necessary by whichever method the seed has been collected and dried, and should take no longer than 4 to 5 hours in a hot sun by which time, on turning the seed, no movement of the seed should be observed. For storage, the bottom layer of sacks should be raised off the floor on wooden slats to allow air circulation and to prevent ' sweating '. At its maximum in December, germination seldom exceeds 25 per cent, and by planting time (May) germination may be only 10 per cent, becoming practically nil at the end of 10 months.

PREPARATION OF SEED BED AND SOWING

(1) *By mechanical means*

The main object of mechanical clearing and sowing is the rapid establishment of a pure stand of grass which is suitable for subsequent mechanical maintenance. Clearing, which is most economically undertaken if commenced in January–February, consists of bushing, windrowing and heavy disc ploughing. However, if large tracts of land are to be tackled, clearing may well be a year-round operation. Hand labour would be required for digging out odd stumps and roots.

Subsequent cultivation consists of breaking down the soil to a finer tilth and destroying weed growth, using light tractors and attached implements, plus possibly a terracer blade for levelling. This operation should be completed by the *beginning* of May, so that the soil retains a degree of moisture which would be considerably reduced by later cultivation. A final light discing is required immediately prior to sowing to cut back the young weed growth that has appeared during the month of May.

The most practical method of mechanical sowing of jaragua grass seed is by use of a spinner type broadcaster. First of all, the seed must be

mixed with a diluent to obtain a uniform distribution, and so that the broadcaster may handle it satisfactorily. Ordinarily, dry sawdust is used for this purpose, but during the sowing at Central Farm in May 1959, it was found that germination appeared to be very much higher and more rapid by the use of green sawdust. This is probably due to the fact that a certain amount of heating took place in the sacks after mixing. In this case a period of at least 24 hours elapsed between mixing and sowing. During sowing it was found that, on account of the lightness of the sawdust–seed mixture, it was necessary for a man to feed the mixture to the agitator with a stick. By this method it was found possible to sow 25 to 30 acres daily. No compaction by a roller was required after the operation.

(2) *By hand*

Clearing by hand is much cheaper than by mechanical means, and allows revenue to be obtained from the land after the first six months, although the final establishment of pasture takes longer. Employment of labour is usually on a contract basis. Operations to be carried out would consist of under-brushing and felling. Thereafter the cleared bush is burnt in May. Seed would next be broadcast by hand. This leaves stumps and logs remaining, most of which would be eliminated over the following two years during the annual burning of pasture.

In *milpas* (shifting cultivation), land cleared for corn (maize) may be utilized for subsequent pasture. The grass seed is planted with the corn, a small quantity of seed being placed around each hole wherein the corn has been deposited. As corn sowing is usually done uniformly over the plantation, a uniform spread of grass will result, which in time will seed and cover the intervening spaces. The corn grows more quickly than the grass and is in no way affected by the contiguous growth of the grass. A *milpa* which is regularly weeded will also show where any grass seed has failed to germinate, and will enable replanting to be done if necessary.

SEEDING RATES

Seeding rate should be in the region of 20 lb/acre and distribution of seed must be even. This seeding rate will not only ensure rapid establishment but also reduce subsequent weed competition. The exception is the *milpa* method of establishment, which usually requires a lighter seeding rate, about 12 lb/acre being normal.

Planting by cuttings has been tried but is not successful.

MANAGEMENT SUBSEQUENT TO SOWING

Whatever method of land preparation and sowing is employed, the grass must be allowed to seed out naturally in the first December after sowing.

(1) *On land mechanically prepared*

The seed is allowed to germinate and establish roots. No cutting or grazing can be carried out during the first six months. In most areas of land in this country subsequent to land clearing, a vigorous growth of natural grass known locally as *kanchim* (*Panicum fasciculatum* Swartz) is to be expected immediately after the onset of the rains. Therefore it is imperative that sowing should be carried out on freshly disced land, otherwise this

vigorous grass will cover and prevent the germination and growth of the jaragua seed. The *kanchim* will not harm the grass, provided the two grow together. During the months of June and July the *kanchim* will be predominant, but in August it will die off, exposing the young iaragua shoots to the sunlight, which results in an increased rate of their growth. The jaragua is left to grow and seed naturally in December. If no *kanchim* is present, other weed competition is of no importance.

After the grass seeds in December, it should be heavily grazed for the first time to aid distribution of seed, and to eliminate as much bulk as possible to allow the passage of machinery. The length of first grazing depends on the number of cattle available, and how long it takes them to eat the green shoots and flatten the dry stems, but the aim is to have the flattening and seed distribution completed by early February, so that mulching of the land by bush-hogging (bush hog set as high as possible) will provide dry-weather fodder for April and May. February and March showers will be conserved by the mulching, and also the bush growth during February is in its early stages and can be handled by a bush hog without fear of damage to machinery.

Light grazing can then be obtained from the growth after bush-hogging. The aim should be to maintain a 4 to 6 in. stand of grass until the latter part of April when the dry season will be most severe. This cover reduces soil temperature and helps to conserve moisture.

From late April onwards, when there is normally no rainfall, the grass may be grazed closely. Before the onset of the rains, the mulch should be burnt to allow the seed produced in December, and which is underneath, to germinate. All stock should then be removed from the area, which should *not be grazed until the seedlings have reached a height of 8 to 12 in.* and established themselves. A simple test is to be able to break off a small handful of young grass without disturbing the roots.

In Stann Creek and Toledo, burning can sometimes be done in January, because enough rain can be expected in February and March to germinate the seed and establish the seedlings sufficiently to carry them through the dry season. In Cayo and the north burning should be done in May only.

Thereafter the pasture is established if the original distribution of seed has been uniform. If not, the area may be grazed until the end of September, when stock should be removed to allow seeding in December.

Sowing of seed *may* be carried out in early January if the seed bed happens to be ready then. The subsequent light rains which are normally to be expected will be sufficient to establish the shoots by the end of March. Light grazing from mid-April to the end of September can be undertaken, but care is required to prevent damage to growing young grass.

The time between sowing and complete establishment may be reckoned to be 14 to 16 months, during which period some grazing may be obtained from the area, particularly in the second half of the dry season when natural pastures are unproductive.

(2) *On land prepared by hand or as* milpa

The seed is sown not later than three days after burning the felled area, so that it is able to compete with weed growth. *Kanchim* will usually grow in the manner already described. In December, cattle are first grazed on the area, thereby eliminating most of the top growth, and spreading seed as before. As cutting is not practicable by mechanical means, and the results obtained by hand cutting at this stage do not warrant the expenditure, the cattle are removed in late January to early February, leaving the flattened grass to grow back. Regrowth of the grass takes place at the nodes. This growth provides dry weather fodder until the end of the dry season. Towards the early part of May, any weed growth should be roughly chopped by cutlass and allowed to dry for burning when weather conditions denote the probable onset of the rains.

After burning, which will usually dispose of the majority of stumps and logs, all cattle should be removed as previously described. Treatment of the pasture is the same as for mechanical establishment, except that re-seeding in the following December is vital because the initial distribution of seed by hand will not be as uniform as by mechanical means. The time between sowing and complete establishment under average conditions will be around 30 months.

In the *milpa* method of establishment, corn is taken off in the first year only during October–November. Thereafter management is as described and grazing will first be available in December as usual.

COST OF ESTABLISHMENT

(1) *By mechanical means*

SALGADO (1939) gives costs of establishing jaragua grass in Brazil. The costs given here are based upon the establishment of 180 acres at Central Farm in 1959. Current prices for clearing bush, windrowing and one heavy cultivation range from B.H. $45 to $80 per acre according to the density of the bush. Operations required generally are as follows (B.H. $4.00=£1):

	Per acre
Clearing, windrowing, heavy cultivation	B.H. $80.00
Stumping and removing of roots, by hand	3.00
Disc-harrowing twice	8.00
Terracing, if required	1.00
Pre-sowing discing	4.00
Sowing: labourer, tractor, fuel, etc.	1.50
Seed (20 lb/acre)	8.00
Mixing seed: collection of sawdust	variable
labour, mixing	0.30
Cutting (bush hog) in February	3.50
Construction of fire passes	0.20
Burning	negligible
Total B.H.	$109.50

No estimates are made for fencing as this is governed by individual requirements. However, at Central Farm, using Sapodilla (*Achras sapota* L.) posts 7 ft in length and 9 ft apart with strainers of 8 ft at every forty

yards and carrying four strands of barbed wire, cost for fencing was B.H. $595 per mile, as below:

		Per mile
Labour @ $2.00 per day		$160.00
Posts @ 20*c* each		109.00
Strainer posts @ 40*c* each		17.00
Heavy gauge barbed wire 17 rolls @ $16.00		272.00
Staples		3.00
Transporting posts		34.00
	B.H.	$595.00

On the basis of square 20-acre fields, fencing would thus cost B.H. $21 per acre.

Further costs, which are not easily assessable, will be entailed due to disposal of windrows.

(2) *By hand labour*

1st year		Per acre
Underbrushing and felling		$12 (average)
Construction of fire passes		$ 1
Burning		negligible
Sowing: labour, broadcast sowing by hand		$ 1.50
seed (20 lb/acre)		$ 8.00
2nd year		
Cleaning in May		$ 6.00
Construction of fire passes		$ 1.00
Burning		negligible
3rd year		
Cleaning in May		$ 4.00
Construction of fire passes		$ 1.00
Burning		negligible
	Total	$34.50

The rough cleaning in the second year, in order to ensure a clean burn, is estimated at $6 per acre only, as the grazing of cattle will have to a great extent opened up the area and eliminated most of the weeds. Without the aid of cattle, this operation could cost in the region of $10 per acre.

The construction of fire passes will be required thereafter, whichever method of establishment has been used, whenever burning is necessary due to weed growth from heavy grazing, heavy tick infestation or a high growth of top grass requiring elimination before the onset of the heavy rains.

(3) *By* milpa *method*

Costs for establishment will be the same as under hand labour. However, a gross return of B.H. $32 per acre (average) will be obtained from sale of corn during the first year.

DISPOSAL OF WINDROWS AFTER MECHANICAL CLEARING

If windrows are left to rot, many years may elapse before the windrow area can be graded mechanically and utilized. The most common practice at present is to chop weed growth in the windrows roughly during the months of March and April of the second year; it will then be possible to burn off most of the debris, leaving cohune palms [*Orbignya cohune* (Mart.) Dahlgren] and other species of fire-resistant trees. These are hauled away from the

area at a later date, leaving a strip of uneven, heat-sterilized soil which will grow nothing but weeds for the next two years. This occurs, however, only where high bush has been cleared. Subsequent grading of these areas can only be carried out by means of a crawler tractor.

CARRYING CAPACITY

This varies with season, soil fertility and management. The highest carrying capacity is during the latter half of the year, i.e. from June to early October. During the months of November and December when the grass is seeding, and in the dry months of April and May, the carrying capacity is at its lowest, although it compares favourably with other available grasses. Although as yet no grazing measurements have been undertaken to assess the stocking rate accurately, it is estimated that on reasonably fertile land one breeding cow per acre could be safely maintained on established pasture. For finishing prime beef for market, with knowledgeable management, pasture should carry one head per acre during the latter half of the year and probably one head per two acres during the first part of the year when growth is reduced.

PALATABILITY AND DIGESTIBILITY

The grass is readily eaten in the early stages of growth by animals of every class. Even when mature in November–December it will always be acceptable, except for the stem. AGUILAR (1939) describes the grass as having a high digestibility and producing a prime carcass more quickly than do most grasses.

EXPERIMENTAL WORK

An experiment was carried out from June 1957 to July 1958 to obtain a seasonal yield curve. Clipping was carried out using three different intervals (4, 7 and 9 weeks) on plots of 50 square yards each. There were six replicates. Plots were split to compare the effects of high and low clipping. At the beginning of the experiment a mixed fertilizer (10:15:15) was applied at the rate of 450 lb/acre. The whole of each plot was harvested using a pair of shears.

A sample of approximately 20 g was taken from each cutting from each plot for D.M. (dry matter) and crude protein determinations. The results obtained are summarized in *Table 1*.

Table 1

Frequency of clipping (weeks)	4	7	9
Yield (lb D.M. per acre per annum)	10 900	16 700	16 400
Mean crude protein (% in D.M.)	6·5	5·6	4·7
lb protein/acre	710	930	770

The mean dry matter content was 30 per cent in the rainy season from June to January and 40 per cent from February to May. The reduction in yield caused by too frequent clipping was statistically significant at the

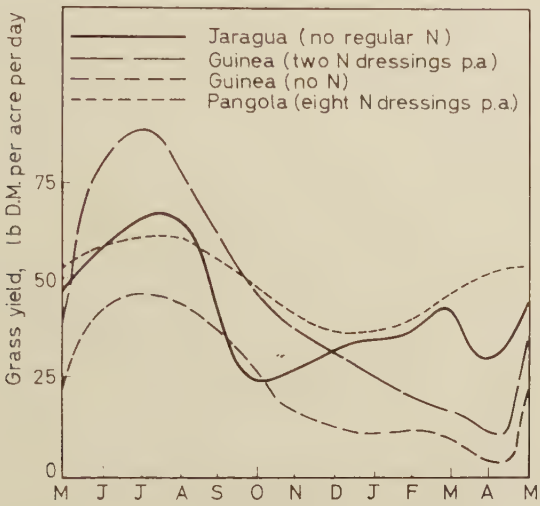

Figure 1. Yield of grass as a function of month of year

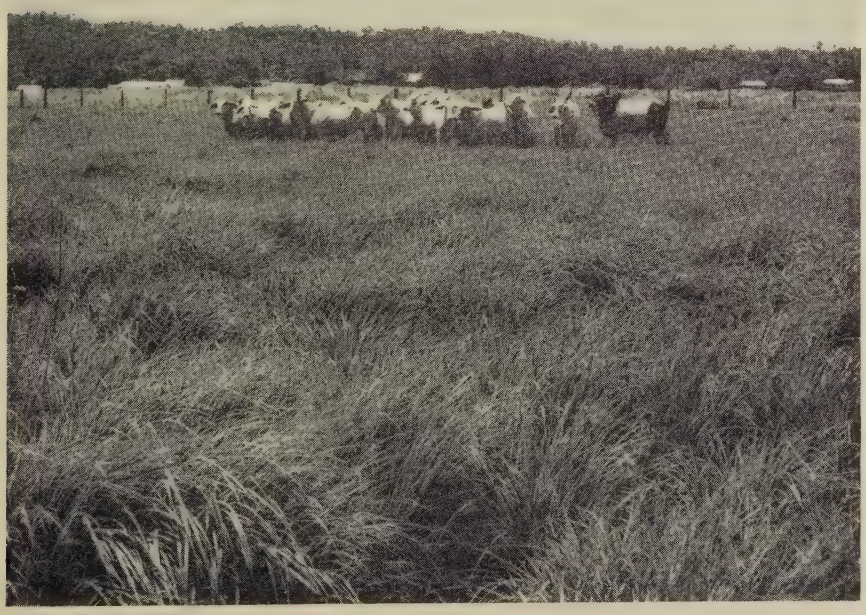

Figure 2. Jaragua grass 13 months after planting at Central Farm of Department of Agriculture

$P=0{\cdot}05$ level. A previous experiment, in which clipping was performed every 21 days, had to be abandoned because of reduction in vigour of the jaragua grass and its replacement by more prostrate species. Continual low clipping (at a height of 2 in.) gave 7 per cent less D.M. per acre per annum than high clipping (at a height of 5 in.), but this difference was not significant, neither was there any deterioration in the sward from the continual low clipping. More recent work has shown that, provided there is a little rain, a dressing of 100 lb/acre sulphate of ammonia (21 per cent nitrogen) increases yield of dry matter over control as much as threefold in six weeks and raises the protein content by about one per cent.

The mean crude protein content of jaragua grass, not receiving regular nitrogen dressings and cut every seven weeks, was 5·6 per cent. Unfertilized guinea grass cut every six weeks had a mean crude protein content of 7·0 per cent. Regularly fertilized pangola grass cut every six weeks had a mean crude protein content of 6·3 per cent, ranging from 3·7 per cent to 9·1 per cent (ROMNEY, 1961).

The yield curves shown in *Figure 1* indicate that jaragua grass not receiving nitrogenous fertilizer gives yields of 16 000 lb D.M. per acre per annum, which appear to compare favourably with unfertilized guinea grass (9 000 lb D.M. per acre per annum), and guinea grass given two dressings each of 200 lb/acre sulphate of ammonia in 12 months (16 000 lb D.M. per acre per annum). Pangola grass given eight dressings per annum each of 50 lb per acre sulphate of ammonia yielded 22 000 lb D.M. per acre per annum. The curves shown are not all for the same year but the satisfactory production of jaragua grass in the dry months of February to May inclusive is evident and this is borne out by grazing experience.

SUMMARY

The place of Jaragua grass (*Hyparrhenia rufa*) as a pasture grass in British Honduras is described. The establishment and management are detailed, together with the costs of the various operations. Establishment is shown to take not less than 14 months. A clipping experiment of 12 months duration is used to provide seasonal yield information. An annual production of 16 000 lb D.M. per acre per annum is demonstrated, with very little reduction in growth during dry weather.

ACKNOWLEDGEMENTS

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Book Reviews

POULTRY KEEPING IN INDIA

P. M. N. Naidu. Indian Council of Agricultural Research: New Delhi, 1959. *xviii*+293 *pp.* (illus.) *Rs* 19.80

The author of this publication is to be complimented on a remarkable achievement in providing a readable textbook for the more advanced poultry farmers of India. Most textbooks concerned with one aspect of animal husbandry are merely condensations of, or additions to, previously published works, and it is refreshing to find a book written by an Indian, which really deals with the poultry industry of India with full reference to Indian conditions and with original photographs taken on Indian poultry farms. The book deserves to be widely read in India, and should stimulate teachers and research officers to produce similar works related to the particular conditions prevailing in other parts of the tropics.

As is to be expected, a comprehensive publication of this nature is not without fault, but most of the criticisms which follow are of a minor nature and do not detract from the value of the work as a whole. It is hoped that some of them will be useful to the author in revising the book for future editions.

Table 5 on page 4 gives the all-India fowl population as 86 433 252 and the all-India total poultry population as 94 683 165! As the poultry population of India must change at the rate of several hundred birds per second, it is surely not permissible to quote livestock populations to the eighth place! The reviewer considers a conservative estimate of the error involved in establishing the approximate value of the poultry population at any given time as being at least 20 per cent.

At times the author contradicts himself, and the indiscriminate reader might be confused as a result. Thus on page 34 we read: 'The most important consideration in the choice of a breed is that it should be pure-bred'. The author then goes on to point out the definite advantages which may be obtained by the use of cross-breeds, and he refers to the success of the 'Hyline' poultry in the U.S.A. Again, in chapter 5 in a consideration of the environment to be provided for breeding stock, we read: 'conditions that are as near the ideal as possible should be created in respect of housing, feeding, sanitation and general care'. This is contradicted later on in the book when the economic considerations of poultry keeping are discussed, and the point is correctly made that the ideal house or the ideal feeding-stuff may well prove uneconomic in conditions of peasant scale poultry keeping. Again, in the same chapter we read the following description of line breeding: 'The general practice followed is to mate together individuals which are not related closer than first cousins, e.g. a male may be mated to his daughters because he comes from a high producing

female and the daughters are high yielders '. A sire and his daughter are obviously related closer than first cousins!

Although, as stated in the opening sentence of this review, the book is aimed primarily at the literate poultry keeper of India, rather than the advanced student of agriculture, nevertheless insufficient attention is devoted to the process of fertilization in chapter 4. If the peasant poultry keeper is expected to study a detailed diagram of the skeleton of the fowl, with almost every bone labelled with its correct latin name, then he must surely be expected to have at least a working knowledge of the male and female reproductive systems. The process of fertilization, and the method by which semen may be stored inside the hen, is badly skimped.

Various simplifications appear in this book which can be quite readily corrected, thus, in the section on ' out-crossing ' in chapter 5, the following naïve assumption is made: ' One strain of White Leghorns may possess high egg production characteristic, but the eggs may be of small size. Another strain of the same breed and variety may be only reasonably good egg producers, but may lay eggs of large size. By crossing these two strains, it is expected that while egg production does not suffer materially, egg size will improve '. In fact, it may be confidently expected that certain of the off-spring will retain the bad characteristics of each parental strain! Failure to point out this simple fact is to offer false promise to the would-be poultry breeder. The section on sex-linkage, again in chapter 5, is poorly handled and it is not made clear to the reader which sex of the domestic fowl is homogametic and which sex is heterogametic. It is surely of importance and relevance to point out that the avian differs from the mammal in this important genetic characteristic.

Certain sections of this book are extremely well-written and improve upon the quality of previous textbooks dealing with the same subject. Thus the author must be complimented on chapter 7 and the extensive coverage given to various methods, both primitive and modern, for incubating eggs and for rearing young chicks in India. The only fault to be found with this chapter is that it contains an incongruous coloured copy of a commercial chart produced by Dr SALISBURY and dealing with a highly over-simplified presentation of the life-history of tapeworms and roundworms of poultry. Neither of these important parasites has anything to do with the subject matter of this chapter.

The book is most amply illustrated with text figures and with photographs, most of which serve their purpose extremely well. However, one or two photographs could well be omitted, for instance, the photograph of an electric colony brooder presented in figure 79, which is either badly out of focus or else has been over-enlarged.

In general, the text reads very smoothly, is simple to understand and avoids repetition. However, one minor instance of unnecessary repetition is to be found on page 124, when the symptoms of under-heating and over-heating of chicks in primary brooders are stated twice in the same paragraph.

All things taken into consideration, this is a useful and constructive addition to the agricultural literature on animal husbandry subjects. Its purchase at the price of Rs 19.80 can be confidently recommended.—P.N.W.

THE MANGO
Botany, Cultivation and Utilization

LAL BEHARI SINGH. Leonard Hill: London, 1960. *xiii*+438 *pp.* (illus.) 84*s*

This appears to be the first of the *World Crop Books* under the general editorship of Professor NICHOLAS POLUNIN which are being published by Messrs Leonard Hill. Dr LAL BEHARI SINGH, Director of the Horticultural Research Institute, Saharanpur, India, who claims that the mango has the largest area under any single fruit crop in the tropics, has produced a comprehensive account of the botany, cultivation and utilization of this ' King of Indian fruits '.

The longest chapter, of 73 pages, deals with all aspects of propagation. There are very good chapters on diseases and pests, and most aspects of the crop appear to have been adequately dealt with. The chapter on varieties (I prefer the use of the word cultivars) deals mainly with those found in India, some of which are illustrated in colour. A list of important Florida cultivars is given, as well as short lists from other parts of the world. Those from the West Indies are not included, so those deservedly popular cultivars ' Peter ' and ' Julie ' are not given. CHANDLER (1958) in *Evergreen Orchards*, 2nd ed., considers that ' Peter ' originated from the Indian cv. ' Apple ', also known as ' Mango Blanca ' or ' Bombay ', while the widely planted ' Julie ' seems to have come to the West Indies from Réunion, where it is thought to have originated as a cross between ' Divine ' and ' Or ', both descended from cultivars or seedlings introduced from India.

The book is profusely illustrated with line drawings and photographs which are of a high standard, and there is an extensive bibliography. Here then is an attractively produced book, which is likely to be the standard work on all aspects of mango production for many years to come. We look forward to the publication of books on other crops listed in the series which ' is designed to fill a widely felt need for general books on individual crops or groups of crops of world importance '.—J.W.P.

THE ECONOMIC BACKGROUND TO AGRICULTURAL POLICY

EDITH H. WHETHAM. Cambridge University Press: London, 1960. 147 *pp.* 22*s* 6*d*

The reader of this compact and competent review of the economic factors at work in agriculture should, if he is concerned with matters of policy in less developed countries, commence with the last paragraph of the text. No conscious policy for agriculture, except apparently negative ones enumerated by the author among her Conclusions, is likely to achieve plenty for the whole of a poor community (if it is not to live on international charity). The other objects of agricultural policy listed by the author—Strategy, Stability, Equality—all conflict to some extent with Plenty and the poor community cannot usually in the long run afford them.

Indeed the reviewer's misgiving on picking up this book was that it might be too much concerned with Policy and not enough with Economic Background to be really useful to the worker in the tropics. This, however,

proves not to be so; the bulk of the work is concerned with the basic theory of markets, prices and factors of production. These matters are discussed with clarity and economy. The general arrangement and the weight given to certain sections do not always agree exactly with the reviewer's choice but this is understandable in a book that is not primarily concerned with conditions of economic underdevelopment. It is indeed a pleasant surprise that the work contains so much basic discussion which can be read with just as much profit by the worker in the tropics as the student of one of the least agricultural countries in the world.—A.L. J.

PLANT EXPLORATION, COLLECTION AND INTRODUCTION

R. O. WHYTE. *F.A.O. Agricultural Studies No. 41.* U.N.F.A.O.: Rome; Her Majesty's Stationery Office: London, 1958. *ix*+117 *pp.* (illus.) 5*s*

Dr WHYTE's very readable booklet gives a brief review of the history of domestication and movement of several tropical and temperate crop plants, some of which might benefit from the collection and use of new material in improvement projects. He presents views on the rationale of plant collecting, introduction and use, and suggests means of coordinating this important work through an international organization such as F.A.O. —F.W.C.

IRRIGATION BY SPRINKLING

A. MOLENAAR. *F.A.O. Agricultural Development Paper No. 65.* U.N.F.A.O.: Rome; Her Majesty's Stationery Office: London, 1960. 93+*vii pp.* (illus.) 5*s*

In *Irrigation by Sprinkling* the author has dealt mainly with sprinkler systems and equipment rather than the broader subject of sprinkler irrigation.

The first few pages are devoted to reviewing the merits of sprinkler irrigation. This is followed by a description of the main components of sprinkler irrigation systems and the range of equipment on the market. Here, the author is much to the point and has sensibly avoided details which more properly belong to manufacturers' catalogues and bulletins.

The next section, and perhaps the most important one, is concerned with the procedures followed in designing a sprinkler irrigation system. The considerations are taken in logical sequence and in clear simple language. This is ably supported by an appendix setting out four simple examples of possible sprinkler system designs for an area. Comparative costings of the systems are included and they are of value only as a guide to the exercise.

The section on operation and maintenance could have been more thoroughly covered, bearing in mind that the vast majority of present underdeveloped territories, for which this publication will have greatest appeal, is rarely, if ever, supplied with adequate dealer service.

The printing is good, though a couple of errors (page 42, ' log ' laterals for long laterals and page 66, ' 1 inch ' per hour for 0·1 inch per hour) remained undetected. Illustrations are numerous but good, and they make the descriptive sections more interesting.

Such a publication should readily find a place as a good reference for Agricultural Officers in Extension Services and it has come at a time when

there is increasing awareness and acceptance of the important role of soil moisture in crop production.—L.G.C.

DIE NUTZPFLANZEN DER TROPEN UND SUBTROPEN DER WELTWIRTSCHAFT

I. Esdorn. Gustav Fischer Verlag: Stuttgart, 1961. 159 *pp.* (illus.) *DM* 24.00

The avowed aim of the author is to provide a modern text on tropical and subtropical economic plants for German students of commerce and technology. Her book includes useful notes on the botany of each plant, often accompanied by line drawings; fairly full accounts of the uses of each product; some chemical analyses, and statistics of trade with special reference to German commerce. Such information as is given on the cultivation and distribution of each crop tends to be fragmentary and superficial and often seems hardly up to date; there is more knowledge than this in Germany, but it is not deployed here.

The book will no doubt usefully fill a gap, and in view of the present volume of German imports from the tropics any increase of understanding in the trade is to be welcomed.—G.B.M.

ESTUDOS AGRONÓMICOS

Vol. I, No. 1, Jan–Mar, 1960. 81 *pp.*

This is the first issue of a new quarterly journal published by the Commission for Overseas Agricultural Studies of the Portuguese Overseas Ministry. It is stated that it will not be for sale, but will be distributed free or in exchange (Missão de Estudos Agronómicos do Ultramar, Rua Rodrigo da Fonseca 103–4°, Lisboa 1, Portugal).

This first number contains 7 articles, of which two are in English including the longest article which describes the soils of Portuguese Guinea. The remaining articles are in Portuguese with English summaries. Contributions will be acceptable in Portuguese, Spanish, French, English or German.

We wish this new contemporary the success and usefulness which the purposes that it serves deserve.—G.B.M.

Recent Publications

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

Memoirs—Economic Series No. 2: Peasant Farming, 1*s*; No. 3: Readings in Small Scale Farming, 5*s*; No. 4: Clip-Card Accounting on the Farm, 8*s* 4*d*

A Notebook of Tropical Agriculture. 6th ed. rev. and enl. 1957. 12*s* 6*d*

THE REGIONAL RESEARCH CENTRE OF THE BRITISH CARIBBEAN

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No. 5 British Guiana. The Mahdia Valley, The Bartica Triangle, The Kamarang and Kukui Valleys, A Part of the Upper Mazaruni Valley 1959, 14*s*

No. 6 British Guiana. The Rupununi Savannas (continued). The Intermediate Savannas. General Remarks. 1959, 15*s*

No. 7 Jamaica. Parish of Clarendon 1959, 20*s*

No. 8 Jamaica. Parish of St James 1959, 12*s* 6*d*

No. 9 Grenada. 1959, 18*s*

No. 10 Jamaica. Parish of St Mary 1960, 14*s*

These and earlier publications can be obtained from the Library and Publications Department, Faculty of Agriculture, University College of the West Indies, St Augustine, Trinidad

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The following books written by members of the staff have recently been published:

Insect Life in the Tropics, by T. W. Kirkpatrick. Longmans, Green: London. 35*s*

Bananas, by N. W. Simmonds. Longmans, Green: London. 45*s*

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Infectious Diseases of Animals is a multi-volume work which provides a critical and well-referenced account of the state of our knowledge of the more important diseases of animals, each being dealt with by a leading expert in the subject concerned. The Editors have first considered the needs of post-graduate students in the veterinary field, in human medicine and in public health, but have borne in mind the requirements of research workers, clinicians, students and others for a reference work in the field of animal diseases.

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